SPRING USE OF THE MACKENZIE RIVER BY SNOW GEESE

IN RELATION TO THE

NORMAN WELLS OILFIELD EXPANSION PROJECT

P.N. Boothroyd

Canadian Wildlife Service

Winnipeg, Manitoba

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CANADIAN WILDLIFE SERVICE

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ABSTRACT

The influence of Esso's oilfield expansion project at Norman Wells on spring use of local staging habitat by snow geese was investigated in 1983 and 1984. Aerial surveys of the Mackenzie River were flown to determine snow goose use in the Norman Wells area compared to other upstream and downstream habitats. The degree to which various environmental factors influence snow goose migration and staging site selection is discussed. Several reaches of the Mackenzie River were found to be important for snow geese in the study area. The Ten Mile Island - Mac Island reach, in the Norman Wells vicinity, appears to be very important and the most regularly used. The attractiveness of this reach is probably due to the abundance of preferred habitat types. The results of on-site monitoring studies conducted for Esso in 1983 and 1984 are reviewed, interpreted and compared with observations made in previous years. Helicopter support flights were the chief source of waterfowl disturbances associated with the oilfield expansion project. Effects on snow geese were considered to be minor and short-term. Esso's facilities and activities did not appear to deter migrating snow geese from staging in the Norman Wells area. Proposed drilling activities for 1985 and beyond, and operation of the completed oilfield development, are not expected to have significant adverse effects on staging snow geese.

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1. INTRODUCTION

In May 1985, Esso Resources Canada Limited (Esso) completed its oilfield expansion project at Norman Wells, N.W.T., located on the Mackenzie River about 150 km south of the Arctic Circle (Figure 1). The project involved the expansion of oil production from a 100 million m3 reservoir which, in part, lies directly beneath the Mackenzie River. The increased oil production (4400 m3/day from 475 m3/day) is transported by a 870 km-long pipeline, constructed by Interprovincial Pipe Line (NW) Ltd., to Zama, Alberta where it enters an existing pipeline network leading to southern markets. The expansion involved: construction of six production islands in the Mackenzie River to serve as drilling and production platforms to enable recovery of oil from reserves under the river; drilling of nearly 200 wells for oil production and water injection; and installation of a pipeline gathering system to transport production to new processing facilities on the mainland (Figure 2).

During public hearings conducted in 1981 by a Federal Environmental Assessment Review Office (FEARO) Panel, established to review the environmental and socio-economic aspects of the project, the concern was raised that construction and drilling activity on the islands might disturb migrating waterfowl using natural islands in the Norman Wells area in the spring. Another concern was the possibility of a major oilspill occurring during the spring migration period and the serious effect this could have on waterfowl (FEARO 1981).

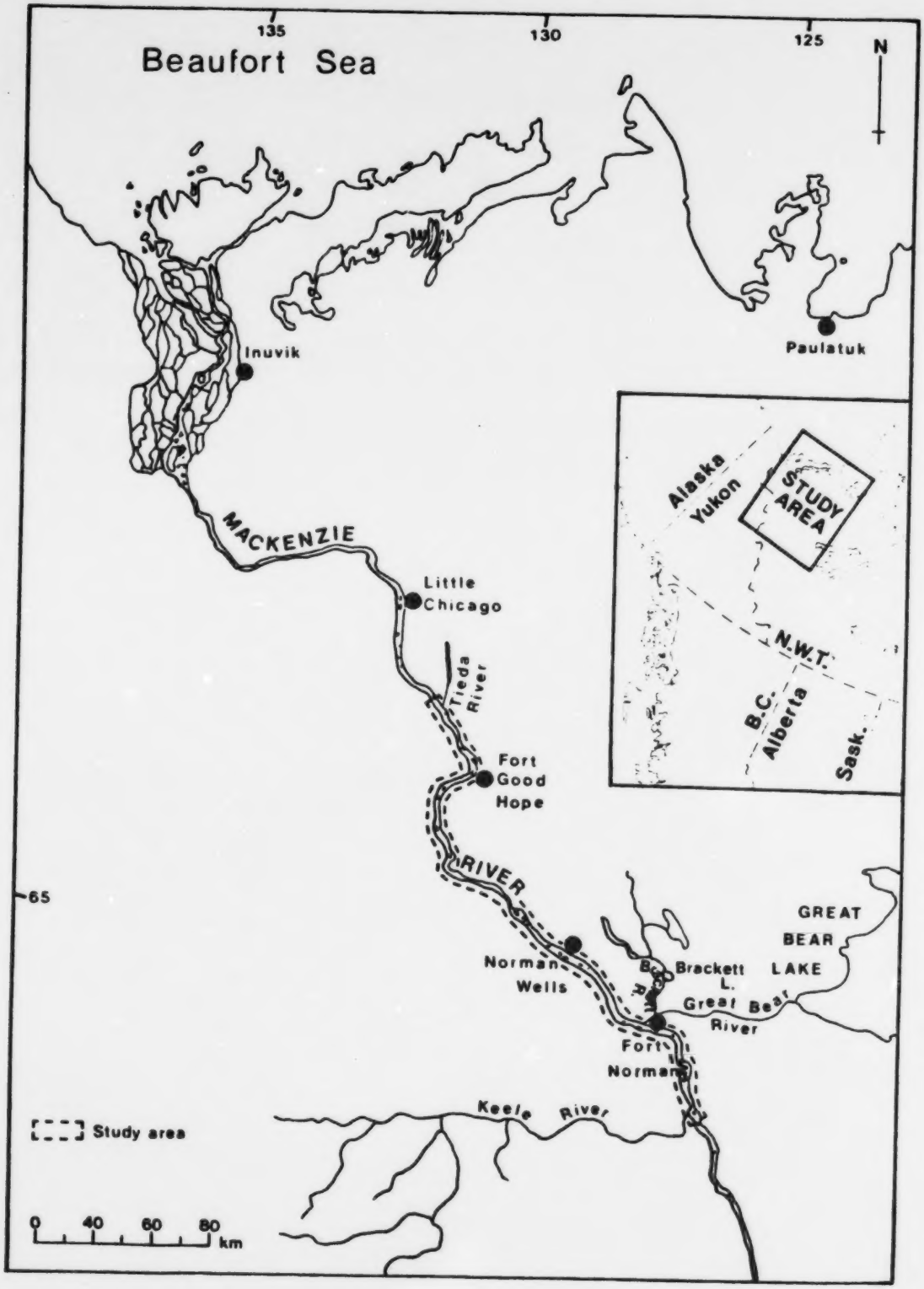


Figure 1. Location of the study area.

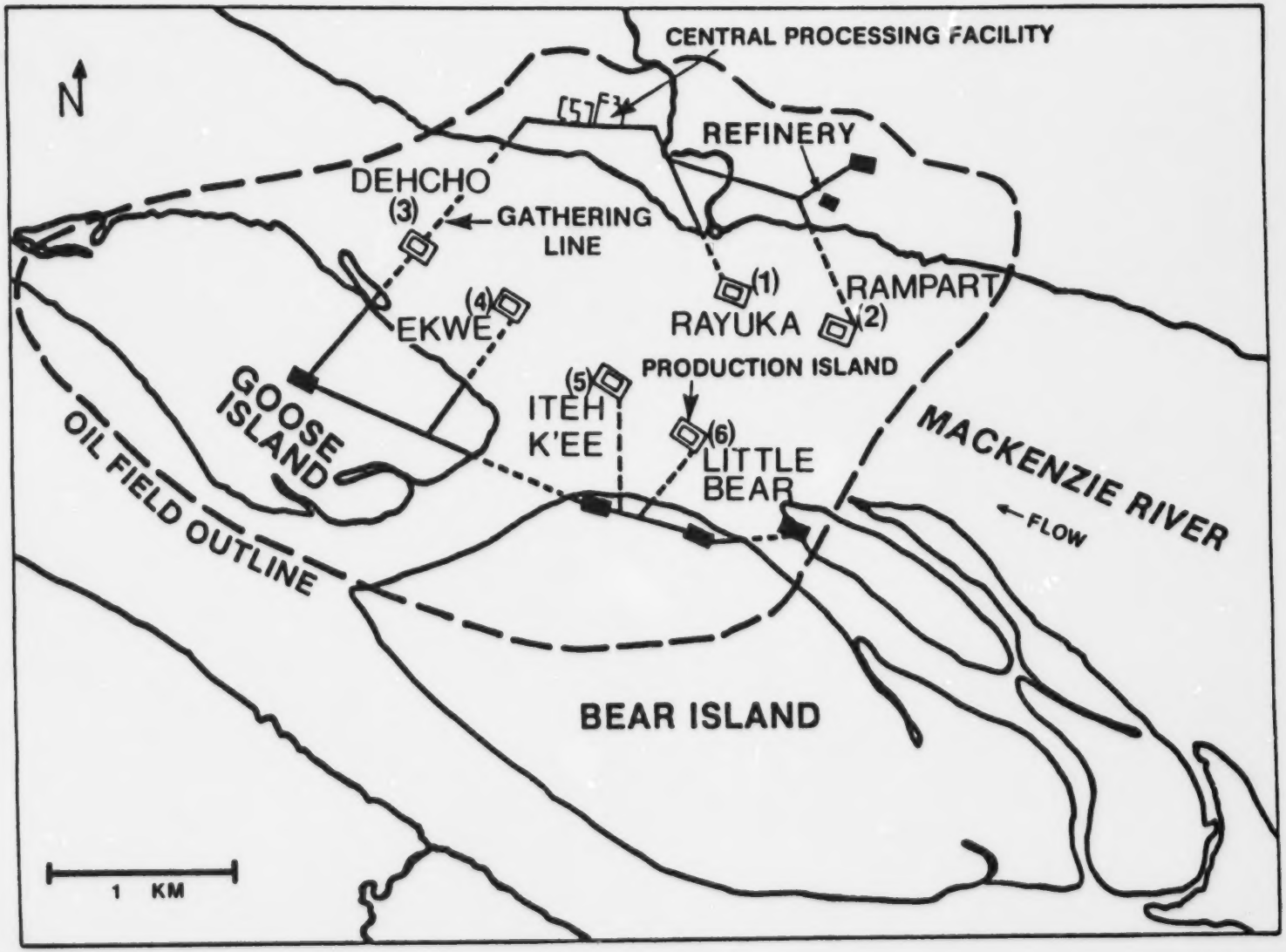


Figure 2. The Norman Wells oilfield expansion project.

The Panel recommended that construction and drilling activity on natural islands and production islands stop during the peak two-week spring migration period and helicopter access to the islands be restricted to only essential needs. In addition, it was recommended that Esso develop a plan specifying the equipment and procedures necessary to keep large populations of waterfowl away from oilspill sites.

Early in 1983, Canadian Wildlife Service (CWS) initiated plans to monitor spring waterfowl (particularly snow goose) use of Mackenzie River islands in relation to the Norman Wells oilfield expansion project. Through consultation with Esso, it was agreed that, in view of the anticipated low level of Esso's activities during the spring of 1983, it would not be necessary for operations to shut down during the entire migration period as recommended by the Panel. This would provide an opportunity for studying the effects of Esso's operations on spring waterfowl populations and habitat use in the vicinity of the expansion project. Consequently, Esso requested and received an amendment to their Drilling Program Approval from the Canada Oil and Gas Land Administration (COGLA) which reduced the standby period for well-drilling.

Esso contracted McCourt Management Ltd. to document and evaluate the disturbance of waterfowl using Bear and Goose islands caused by Esso's project-related activities. It was agreed that, concurrent with the disturbance study, CWS would conduct surveys of the Mackenzie River upstream and downstream of Norman Wells to determine waterfowl use on

a more regional basis for comparison with waterfowl use in the immediate Norman Wells vicinity. More specifically, the purpose of the CWS surveys was to:

(a) determine spring waterfowl staging use of the Mackenzie River islands and shorelines upstream and downstream of Norman Wells; and

(b) determine the relative importance to waterfowl of habitat in the Norman Wells area compared to habitat upstream and downstream.

Following analysis of the waterfowl data collected in 1983, further aerial surveys were planned for 1984 and the purpose of the study was enlarged to also:

(c) determine the relative importance of factors influencing the use of habitat along the Mackenzie River by spring staging snow geese;

(d) assess the influence of the oilfield expansion project on spring snow goose use of Mackenzie River habitat; and

(e) identify key habitat areas important to snow geese in the spring and priority areas for protection in the event of an oilspill originating from the Norman Wells area.

2. STUDY AREA

The study area consists of a 420 km-length of the Mackenzie River from km 740 to km 1160 as measured from where the river issues from Great Slave Lake. The upstream limit of the study area coincides with the inflow of the Keele River, 170 km upstream from Norman Wells. The inflow of the Tieda River, 60 km downstream from Fort Good Hope, marks the northern boundary. Figure 3 shows the location of the study area and geographic features referred to in the text of this report.

The overall climate is sub-arctic in nature with low precipitation and cool summers (Environment Canada 1973). Due to the "continental" location of the study area, weather conditions are less variable than in regions further north and south.

The process of spring breakup of the Mackenzie River is complicated and fluctuates greatly from one year to the next. The factors having the most significant influence on break-up can vary considerably (LaSalle Hydraulic Laboratory Ltd. 1982). However, the Liard River, which collects early snow-melt from the mountainous regions of southeastern Yukon and northern British Columbia, is the major control (MacKay and Mackay 1973). The average date for breakup at Norman Wells, as recorded by Esso Resources Canada from 1945 to 1981, is May 17 (Ealey and Penner 1983). Ice jamming is common and occurs at several locations in the study area (Kamphuis and Moir 1983).

Vegetation communities of alluvial habitats along the Mackenzie River including islands and river banks, are described by Ealey and Penner

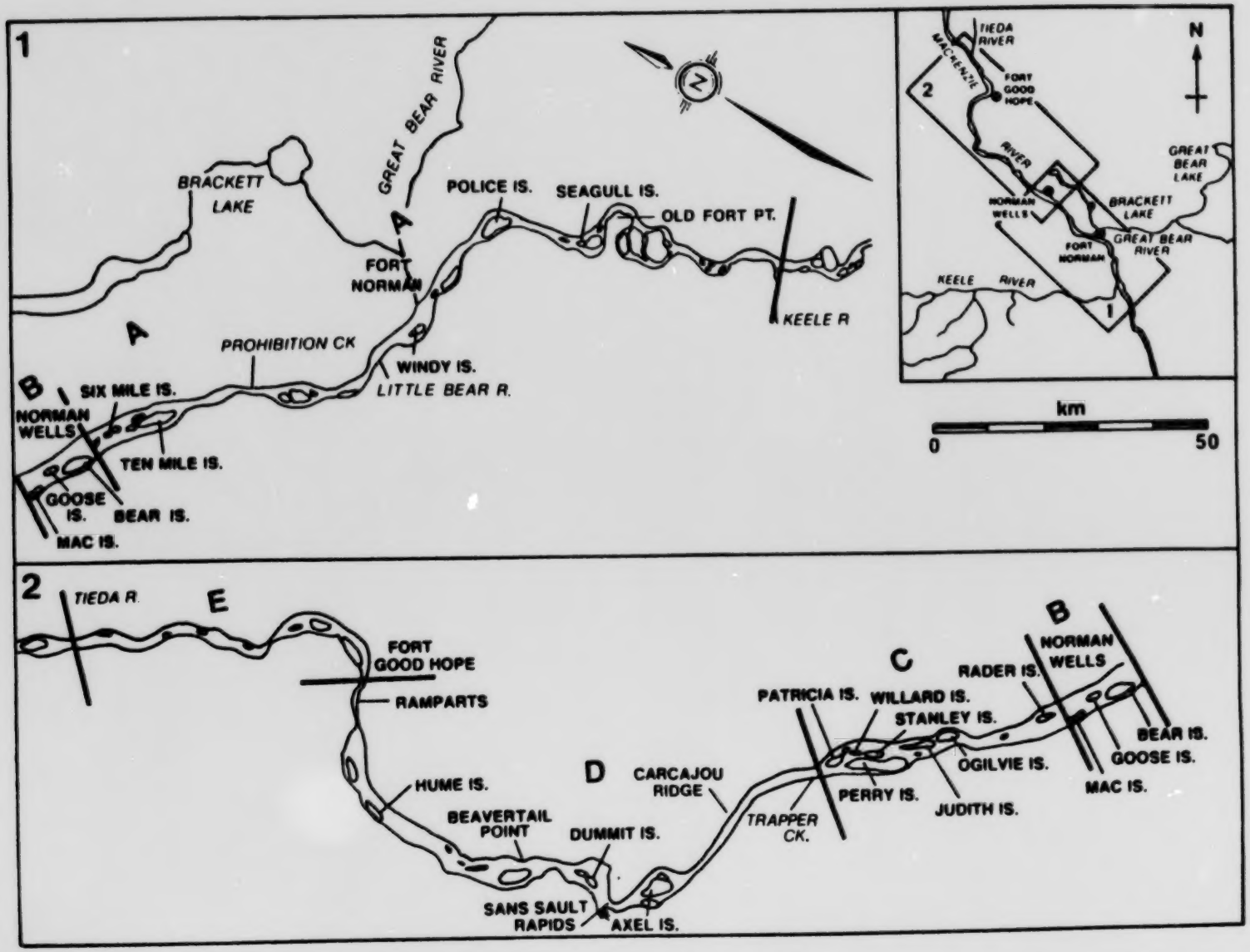


Figure 3. Geographic features and locations of reaches in the study area.

(1983). Ranging from sparsely-vegetated mudflats to white spruce forests, these communities are strongly influenced by hydrological events and are of varying importance to staging waterfowl. The major communities on low-lying alluvial flats and along island margins are comprised of willows (Salix spp.) and horsetail (Equisetum spp.). Ponds and abandoned channels on islands are surrounded by these same species, as well as sedges (Carex spp.), while pondweeds and emergents occur in shallow waters. Trees are found on higher-elevation islands which receive less scouring from ice blocks and undergo less flooding. The predominant tree species on alluvial flats are white spruce (Picea glauca) and balsam poplar (Populus balsamifera). Campbell and Shepard (1973) noted that the frequency of tree-dominated islands, and the proportion of the vegetation communities comprised of trees, decreases as one progresses downstream from Norman Wells. Small islands less than 1.5 km in length are almost totally willow-covered while many islands between 1.5 km and 5 km in size are tree-covered. Large islands greater than 5 km in length are almost totally tree-covered (Ealey and Penner 1983).

The study area lies in the discontinuous permafrost zone (Environment Canada 1973). Depth of the active layer may vary from 0.5 to 3 m depending on local climatic and terrain conditions.

3. METHODS

3.1 Aerial Waterfowl Surveys

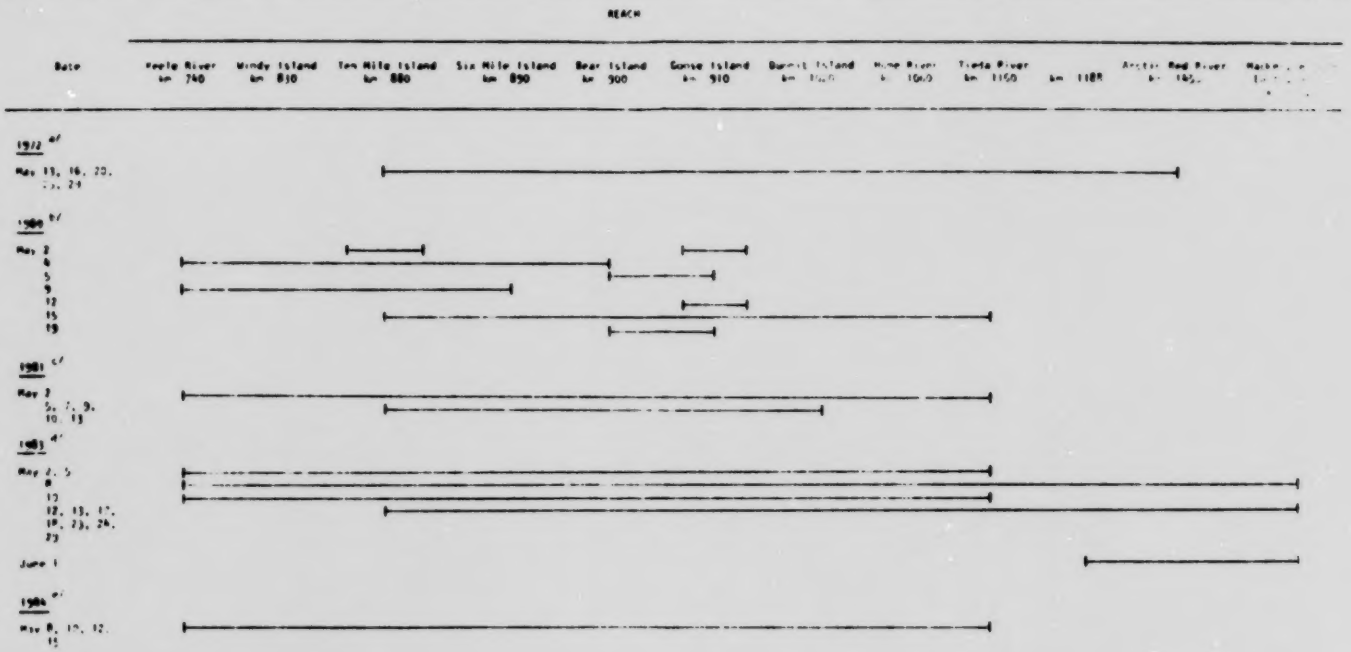
At the time the surveys were being designed, it was discovered that similar surveys of the Mackenzie River were being planned by McCourt Management for B.C. Hydro with respect to the proposed Liard Dam project. The final outcome was that McCourt Management and CWS collaborated on the aerial surveys and exchanged the data collected.

Surveys were conducted by CWS on May 2, 5, and 10, 1983. Each survey covered the river from the Keele River inflow, about 90 km upstream of Fort Norman, to the Tieda River inflow, approximately 60 km downstream of Fort Good Hope (Figure 3). McCourt Management flew surveys on May 8, 12, 13, 17, 18, 23, 24, 29 and June 1. The May 8 survey was flown from Keele River to the Mackenzie Delta. The other May surveys extended from Ten Mile Island (just upstream from Norman Wells) to the Delta while the June 1 survey began about 20 km downstream of the Tieda River confluence and ended at the Delta. Table 1 provides details of the 1983 aerial survey coverage.

Surveys of the Keele River - Tieda River reach were flown again by CWS on May 8, 10, 12 and 15, 1984. In addition, the Brackett Lake area was surveyed for snow geese on May 15 (Figure 1).

All surveys were flown in a Cessna 185 at airspeeds ranging from 135 to 160 km/h and at altitudes between 30 and 50 m above ground level. Two observers recorded birds observed on each side of the aircraft. Locations and numbers of all birds observed during the CWS surveys

Table 1 Reaches of the Mackenzie River surveyed for waterfowl in 1972, 1980, 1981, 1983 and 1986



a/ Campbell and Shepard (1973)

b/ R. Webb Environmental Services Ltd. (1980)

c/ R. Webb Environmental Services Ltd. (1981)

d/ May 2, 5, 10 - Canadian Wildlife Service;
May 8, 12, 13, 17, 18, 23, 24, 29 - McCourt Management Ltd.

e/ author

were recorded directly on 1:50 000 scale N.T.S. maps. Observations made during the McCourt Management surveys were tallied using tape recorders.

3.2 Physical and Resource Data Collection

Temperature, precipitation and wind data for selected meteorological stations in Saskatchewan, Alberta and Northwest Territories were obtained from the Atmospheric Environment Service of Environment Canada. Data on Mackenzie River levels at Norman Wells during spring breakup were obtained from Inland Waters Directorate, Environment Canada, and Esso. Esso also made available low-altitude air photos (various scales) of the Mackenzie River during break-up showing the development of ice leads and open water areas.

Air photos, showing summer conditions of the river at a scale of about 1:64 000, were obtained from the National Air Photo Library for habitat mapping.

Data on snow goose distribution in the study area was compiled for 1972 (Campbell and Shepard (1973), 1980 (R. Webb Environmental Services Ltd. 1980) and 1981 (R. Webb Environmental Services Ltd. 1983). The chronology and pattern of snow goose migration through Saskatchewan, Alberta and the study area in 1980, 1981, 1983 and 1984 was determined from data collected by Environmental Management Associates (1980, 1982, 1983 and 1984, respectively). Information on waterfowl chronology in Saskatchewan in relation to weather and habitat conditions was obtained from Brazda (1980) and Benning (1981,

1983 and 1984).

4. RESULTS

4.1 Waterfowl Distribution - 1983, 1984

4.11 Snow Geese

Numbers of snow geese observed in 1983 and 1984 are summarized by reach in Table 2. Similar data collected by other researchers in 1972, 1980 and 1981, before the oilfield expansion began, appear in the same table for comparison. The 1983 and 1984 observations are tablulated by sub-reach in Appendix I and II. Where known, exact locations of snow goose flocks observed in 1983 and 1984 are contained in Appendix III and IV. Locations of reaches and geographic features are shown in Figure 3.

In the Norman Wells area (Bear Island - Mac Island or reach B) in 1983, peak numbers of snow geese (14 928) were observed on May 18. Maximum numbers (18 930) were present between Fort Good Hope and Tieda River (reach E) on May 23. Sections of the Mackenzie River between Ten Mile Island and Patricia Island and between Fort Good Hope and Tieda River were the most heavily used by snow geese in 1983 (Appendix I).

In 1984, snow geese were already present in the Norman Wells area, and all other downstream reaches, by the time the first survey was flown on May 8 (Table 2). The maximum number of geese present in the study area on any particular date (9 755 on May 10) was only 22 percent of the maximum number recorded in 1983 (44 641 on May 23). In addition, in 1984, geese were more dispersed along the length of the river than in 1983. Preferential use of the Bear Island - Mac Island reach (reach B) and the Fort Good Hope - Tieda River reach (reach E) was not as

Table 2 Numbers and distribution of snow geese observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1972, 1980, 1981, 1983 and 1984.

Reach	Year	2	4	5	7	8	9	10	12	13	14	15	16	17	18	19	20	23	24	25	29
A	1972[a]	[b]	.	.	.	.	.	.	.	22 416	.	.	9 725	.	.	.	681	.	.	[b]	.
(Peele R. - Six Mile Is.)	1980[a]	5 500[c]	16 100[c]	.	.	.	25 975	.	.	.	.	4 700	.	.	.	.	.	.	.	.	.
	1981[a]	20[c]	.	.	25[c]	.	[c]	[c]	.	[c]	.	.	.	.	.	.	.	.	.	.	.
	1983[a]	.	.	.	.	232	.	428	.	25[c]	.	.	.	1 840[c]	12 135[c]	.	.	7 863[c]	[c]	.	[c]
	1984[b]	.	.	.	.	427	.	.	71	.	.	6	.	.	.	.	.	.	.	.	.
B	1972	.	.	.	.	.	.	.	.	12 232	.	.	25 650	.	.	.	3 845	.	.	286	182
(Six Mile Is. - Mar Is.)	1980	3 700	900	7 000	.	.	.	.	.	.	4 600	5 560	.	.	.	.	.	.	.	.	.
	1981	15	.	500	500	.	35	32	.	.	.	.	.	.	.	.	.	.	.	.	.
	1983	.	.	.	.	40	.	782	1 670	1 404	.	.	.	4 279	14 528	.	.	9 062	3 354	.	2
	1984	.	.	.	.	2 225	.	1 098	710	.	.	510	.	.	.	.	.	.	.	.	.
C	1972	.	.	.	.	.	.	.	.	1 573	.	.	5 438	.	.	.	881	.	.	25	.
(Mar Is. - Arctic Red R.)	1980	.	.	.	.	.	.	.	.	.	.	5 025	.	.	.	.	.	.	.	.	.
	1981	400	.	750	.	.	.	.	.	5	.	.	.	.	.	.	.	.	.	.	.
	1983	.	.	.	.	90	.	45	352	907	.	.	.	1 100	715	.	.	5 361	6	.	.
	1984	.	.	.	.	2 286	.	2 017	1 811	.	.	736	.	.	.	.	.	.	.	.	.
D	1972	.	.	.	.	.	.	.	.	6 375[d]	.	.	6 948[d]	.	.	.	6 230[d]	.	.	1 529	83
(Travaller Ck - Ramparts)	1980	.	.	.	.	.	.	.	.	.	.	250	.	.	.	.	.	.	.	.	.
	1981	180	.	[b]	[b]	.	.	[b]	.	[b]	.	.	.	.	.	.	.	.	.	.	.
	1983	.	.	.	.	80	.	.	10	2	.	.	.	.	.	.	.	3 425	3 462	.	9
	1984	.	.	.	.	3 286	.	5 870	2 002	.	.	2 385	.	.	20	.	.	.	.	.	.
E	1972	.	.	.	.	.	.	.	.	.	.	.	1 050	.	.	.	4 535	.	.	5 529	.
(Fort Good Hope - Travaller Ck)	1980	.	.	.	.	.	.	.	.	.	.	5 400	.	.	.	.	.	.	.	.	.
	1981	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1983	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1984	.	.	.	.	1 100	.	770	1 700	.	.	1 955	.	853	2 315	.	.	18 930	18 214	.	.
TOTALS	1972	.	.	.	.	.	.	.	.	42 544	.	.	48 811	.	.	.	15 372	.	.	7 160	212
	1980	9 200	17 000	7 000	.	.	25 975	.	.	.	4 600	13 935	.	.	.	.	.	.	.	.	.
	1981	615	.	1 250	525	.	35	32	.	5	.	.	.	.	.	.	.	.	.	.	.
	1983	.	.	.	.	432	.	1 255	2 032	2 338	.	.	.	8 072	30 113	.	.	44 641	31 537	.	11
	1984	.	.	.	.	9 322	.	9 755	6 254	.	.	5 552	.	.	.	.	.	.	.	.	.

a/ Carolin I and Shepard (1973)

b/ . = not surveyed

Six Mile Is - Six Mile Is

c/ = snow geese observed

d/ LGL Ecosystem Environmental Services Ltd. (1980)

e/ LGL Ecosystem Environmental Services Ltd. (1983)

f/ May 2, 5 and 10 - CWS; May 8, 12, 13, 17, 18, 23, 24 and 29 - McCourt Management

g/ CWS

h/ Dummit Is - Hume Is

i/ Dummit Is - Ramparts

j/ Traveller Ck - Sans Sault Rapids

pronounced as in 1983.

On May 15, 1984, 6 107 snow geese were present on Brackett Lake which was largely ice-free. This number was greater than the number of snow geese counted during the entire survey of the Mackenzie River that same day (5 592 birds) (Table 2).

4.12 Other Waterfowl

Numbers of dark geese, ducks and swans observed during the 1983 and 1984 surveys are summarized in Tables 3, 4 and 5, respectively. The data are tabulated by sub-reach in Appendices V to X. Peak numbers of dark geese, in the most heavily used Norman Wells and Fort Good Hope - Tieda River areas (reach E), occurred on May 10 and 17, respectively, in 1983 (Table 3). As with snow geese, numbers of dark geese using the river in 1984 were less than in 1983. The reach between Beavertail Point and Hume Island, and to a lesser extent reach E, received the most use. Many of the other reaches were used to a lesser, roughly-equivalent extent.

Ducks (mostly dabblers with small numbers of divers) used every reach surveyed to some extent (i.e. several hundred birds or more) in both 1983 and 1984 (Table 4). Peak numbers of ducks in the study area were recorded on May 24 in 1983 (19 434 birds) and May 15 in 1984 (6 146 birds).

In both 1983 and 1984, reach E was by far the most heavily used by swans (Table 5). As many as 1 015 swans were recorded here in 1983;

Table 3. Numbers and distribution of dark geese observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1983 and 1984.

Reach	Year	2	5	8	10	12	13	15	17	18	23	24	29
A (Keele R. - Six Mile Is.)	1983	725	628	525	2 040	522[a/]	145[a/]	.[b/]	370[a/]	574[a/]	128[a/]	_[a,c/]	_[a,c/]
	1984	.	.	989	190	563	.	101	.	.	.	.	.
B (Bear Is. - Mac Is.)	1983	624	312	280	2 209	842	1 304	.	3 745	1 390	439	110	2
	1984	.	.	667	174	320	.	251	.	.	.	.	.
C (Rader Is. - Patricia Is.)	1983	4	92	956	585	348	508	.	1 097	898	82	180	_
	1984	.	.	753	218	363	.	368	.	.	.	.	.
D (Trapper Ck. - Ramparts)	1983	40	15	133	715	368	644	.	799	1 216	2 013	232	39
	1984	.	.	1 911	2 034	1 421	.	1 750	.	.	.	.	.
E (Fort Good Hope - Tieda R.)	1983	_	_	5	69	81	76	.	340	216	2 018	1 265	3
	1984	.	.	935	574	1 322	.	910	.	.	.	.	.
TOTALS	1983	1 393	1 047	1 899	5 618	2 761	2 677	.	6 351	4 294	4 680	1 847	44
	1984	.	.	5 255	3 190	3 989	.	3 380	.	.	.	.	.

a/ Ten Mile Is. - Six Mile Is.

b/ . = not surveyed

c/ _ = no dark geese observed

Table 4. Numbers and distribution of ducks observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1983 and 1984.

Reach	Year	2	5	8	10	12	13	15	17	18	23	24	29
A (Keele R. - Six Mile Is.)	1983	373	647	881	2 413	524[a/]	602[a/]	.[b/]	1 134[a/]	1 475[a/]	210[a/]	685[a/]	83[a/]
	1984	•	•	1 137	713	592	•	1 587	•	•	•	•	•
B (Bear Is.- Mac Is.)	1983	307	258	596	919	2 744	2 725	•	1 594	5 010	1 574	815	91
	1984	•	•	360	200	125	•	498	•	•	•	•	•
C (Rader Is. - Patricia Is.)	1983	100	74	50	314	399	854	•	3 081	2 006	1 641	3 176	570
	1984	•	•	245	107	245	•	680	•	•	•	•	•
D (Trapper Ck. - Ramparts)	1983	33	36	52	335	2 096	2 351	•	6 988	6 582	7 705	12 135	1 206
	1984	•	•	3 128	1 665	1 129	•	2 284	•	•	•	•	•
E (Fort Good Hope - Tieda R.)	1983	_[c/]	–	2	24	675	148	•	865	1 146	2 055	2 623	1 446
	1984	•	•	615	544	741	•	1 097	•	•	•	•	•
TOTALS	1983	813	1 015	1 581	4 005	7 038	6 680	•	13 662	16 219	13 185	19 434	3 396
	1984	•	•	5 485	3 229	2 832	•	6 146	•	•	•	•	•

a/ Ten Mile Is. - Six Mile Is.

b/ • = not surveyed

c/ _ = no ducks observed

Table 5. Numbers and distribution of swans observed during aerial waterfowl surveys conducted on the Mackenzie River in May 1983 and 1984.

Reach	Year	2	5	8	10	12	13	15	17	18	23	24	29
A (Keele R. - Six Mile Is.)	1983	–[a]	2	–	42	69[b]	35[a]	.[c]	272[b]	347[b]	11[b]	–[b]	–[b]
	1984	.	.	6	5	20	.	–	.	.	.	.	.
B (Bear Is. - Mac' Is.)	1983	–	1	3	–	30	58	.	10	10	–	4	–
	1984	.	.	–	6	2	.	–	.	.	.	.	.
C (Rader Is. - Patricia Is.)	1983	–	–	–	3	16	2	.	–	13	2	20	–
	1984	.	.	–	–	–	.	–	.	.	.	.	.
D (Trapper Ck. - Ramparts)	1983	–	–	–	1	4	13	.	16	18	98	74	–
	1984	.	.	11	65	84	.	129	.	.	.	.	.
E (Fort Good Hope - Tieda R.)	1983	–	–	–	47	10	8	.	79	207	1 015	487	15
	1984	.	.	5	6	83	.	270	.	.	.	.	.
TOTALS	1983	–	3	3	93	129	116	.	377	595	1 126	585	15
	1984	.	.	22	52	189	.	399	.	.	.	.	.

[a] – = no swans observed

[b] Ten Mile Is. - Six Mile Is.

[c] . = not surveyed

a maximum of 270 swans was observed in 1984. In 1983, as many as 347 swans were noted in the Ten Mile Island - Six Mile Island reach (Appendix IX). However, in 1984, virtually no swans were observed to use the Norman Wells vicinity.

4.2 Historical Snow Goose Distribution

Numbers of snow geese recorded during surveys conducted on the Mackenzie River in 1972, 1980 and 1981 are summarized in Table 2. This data is tabulated by sub-reach in Appendices XI, XII and XIII. Where precise location data were available, sites where snow goose flocks were observed are shown in Appendices XIV, XV and XVI.

Peak numbers of snow geese observed in 1972 were of similar magnitude to peaks recorded in 1983 (Table 2). The section of river between Ten Mile Island and Mac Island, in the vicinity of Norman Wells, was by far the most heavily used by snow geese in 1972 (Appendix XI).

The maximum number of geese seen in the study area in 1980 was about half that observed in 1972. As in 1972, the Ten Mile Island - Mac Island reach was the most intensively used, although significant use was also made of the Keele River - Seagull Island reach (Appendix XII).

Very little staging use was made of study area in 1981. Use was almost totally limited to the Norman Wells area.

Snow goose observations made during the above surveys were combined with those made in 1983 and 1984 to produce the snow goose distribution maps of Figure 4. Extreme caution must be used in drawing conclusions from these maps; specific locations of goose sightings were not available for some of the surveys due to either the survey methods used or the manner in which the data was compiled. A number of surveys did not include reaches upstream from Ten Mile Island or areas downstream from Goose Island (Table 1). However, the maps clearly show that certain locations along the river tend to receive considerably more use by staging snow geese than others.

In the immediate Norman Wells area, Ten Mile, Six Mile, Bear, Goose and Mac islands, and the unnamed island directly downstream from Goose Island, have all been used regularly in the spring. Further downstream, the area across from Ogilvie Island, and sites on and adjacent to Patricia, Willard and Stanley islands, received somewhat less use. The collection of small islands and mudflats downstream from Beavertail Point have been used substantially. Certain islands downstream from Fort Good Hope have received moderate use.

4.3 Habitat Distribution

The maps of Figure 5 show the distribution of habitat consisting of either sparsely-vegetated mudflats, moderately well-vegetated areas with *Carex* and *Equisetum* with or without willow growth, or combinations of these communities. Such habitat types are preferred by staging snow geese.

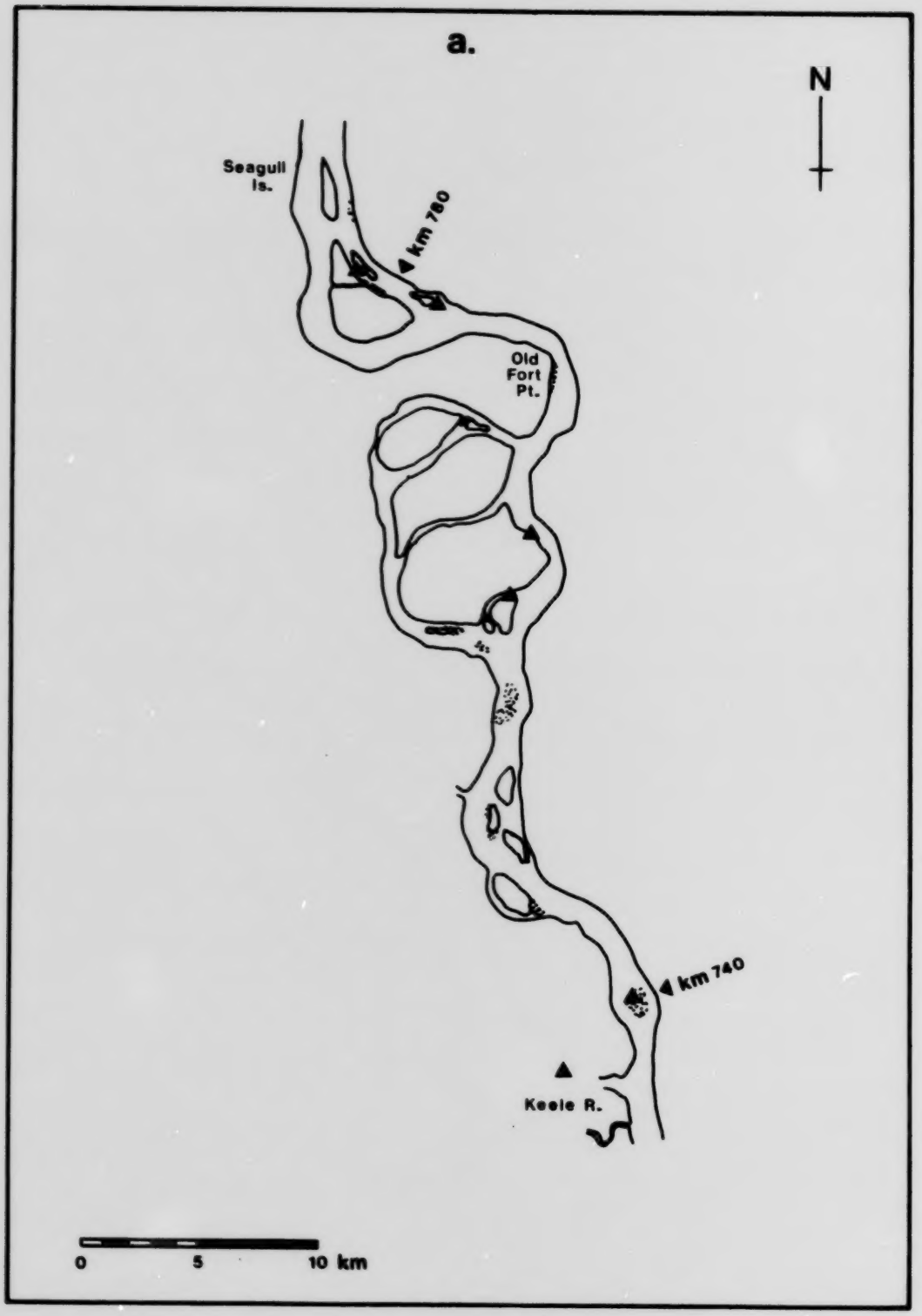


Figure 4. Locations of snow geese observed during aerial surveys flown in 1972, 1980, 1981, 1983 and 1984 combined.

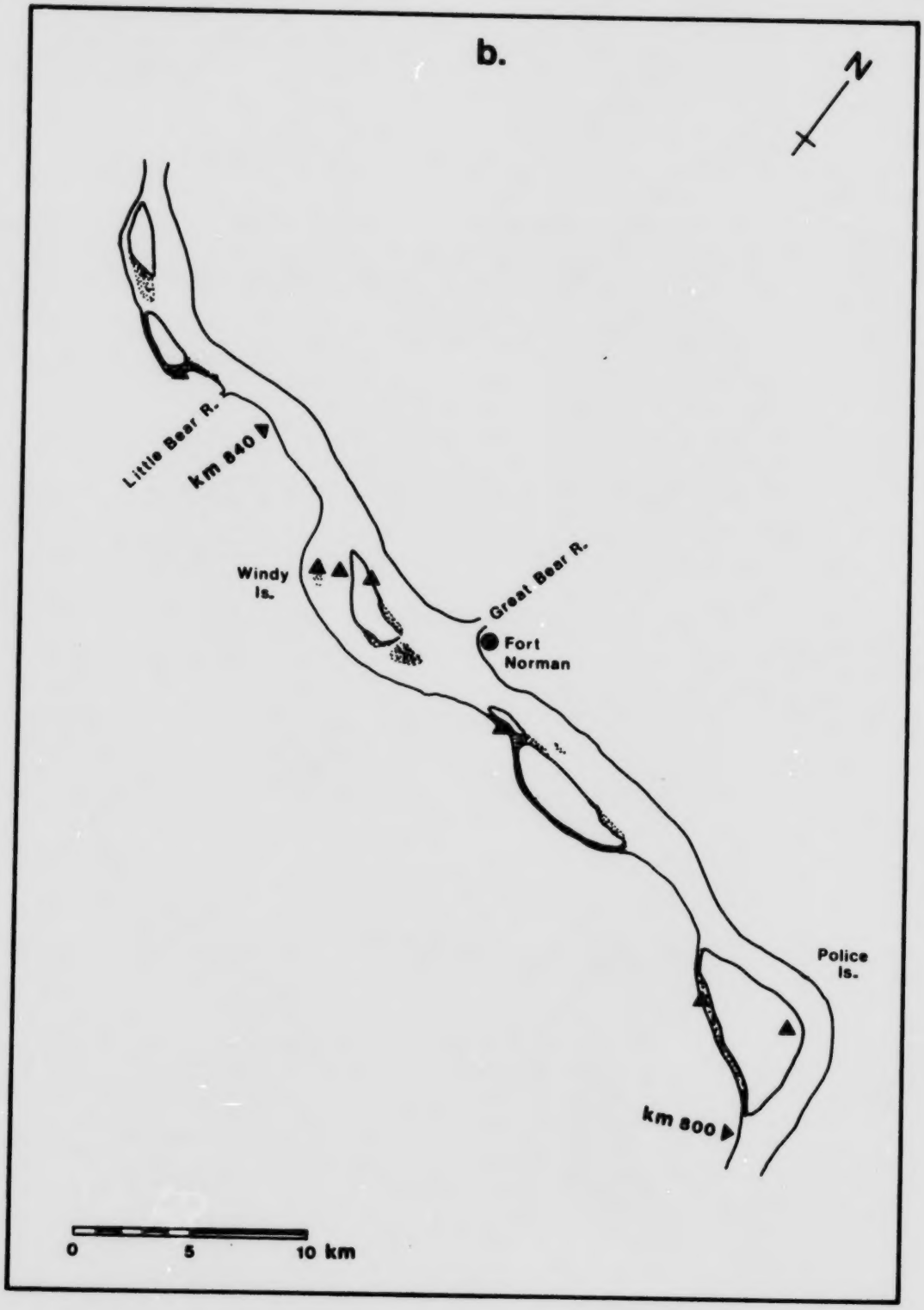


Figure 4. (cont'd)

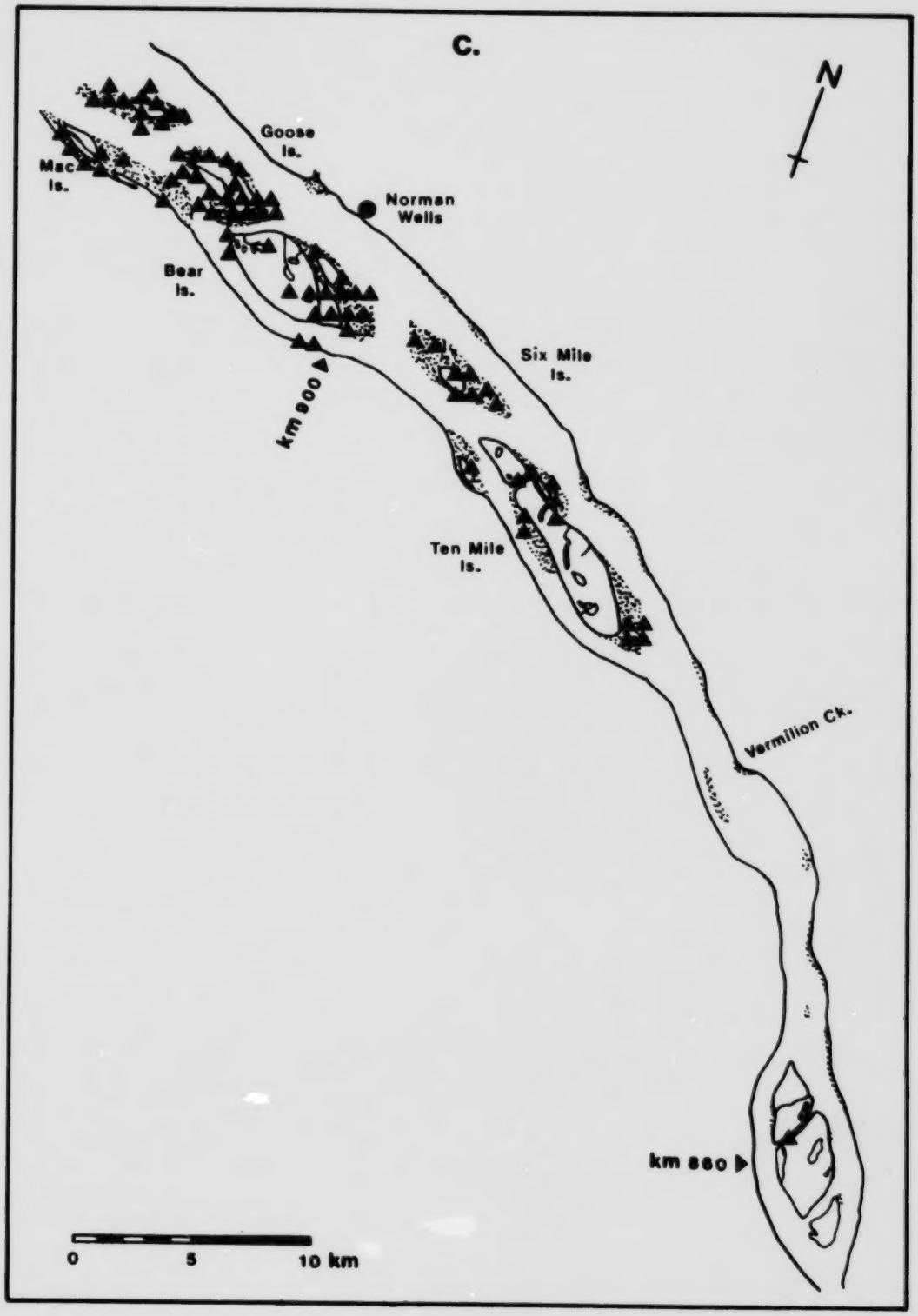
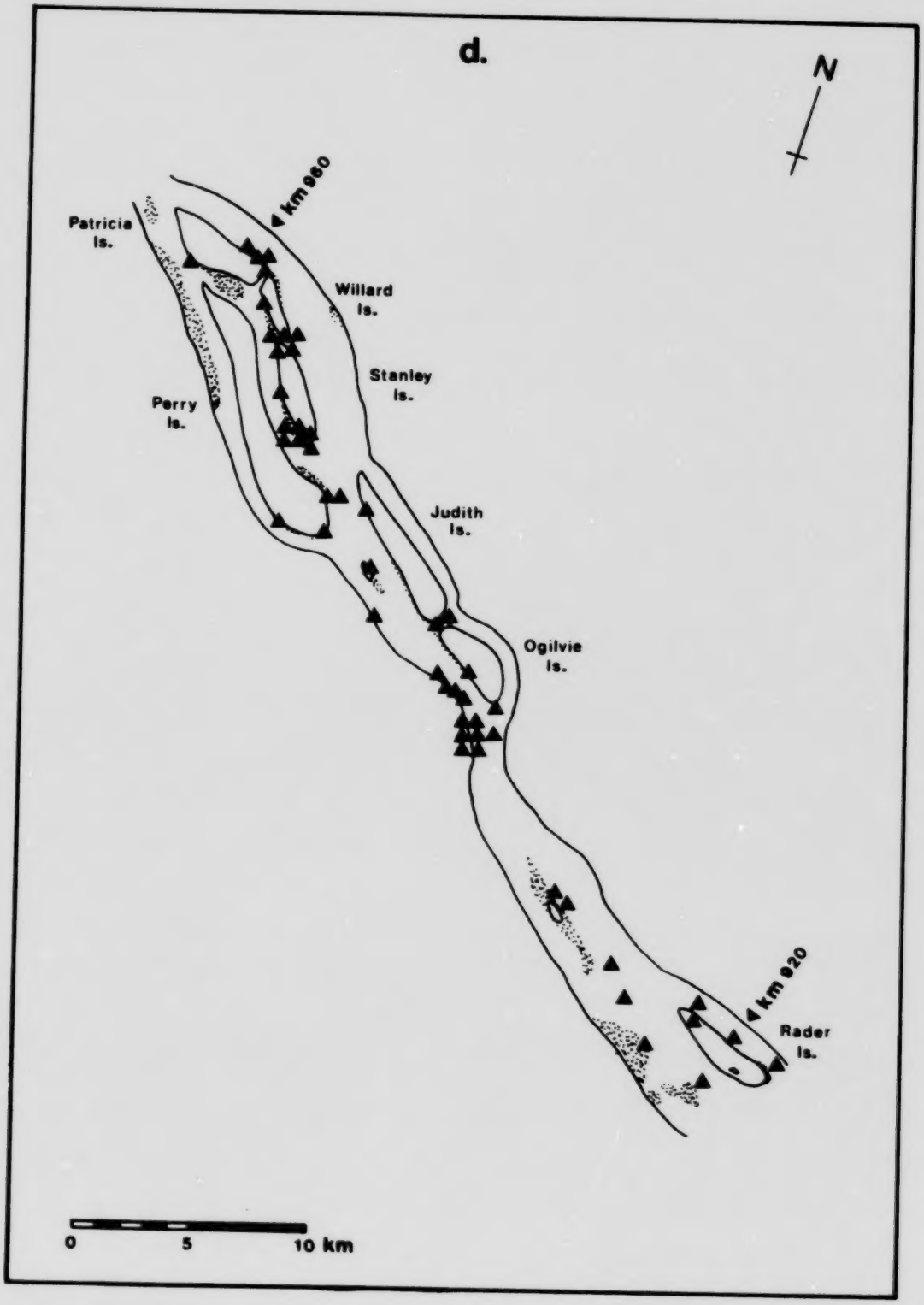


Figure 4. (cont'd)



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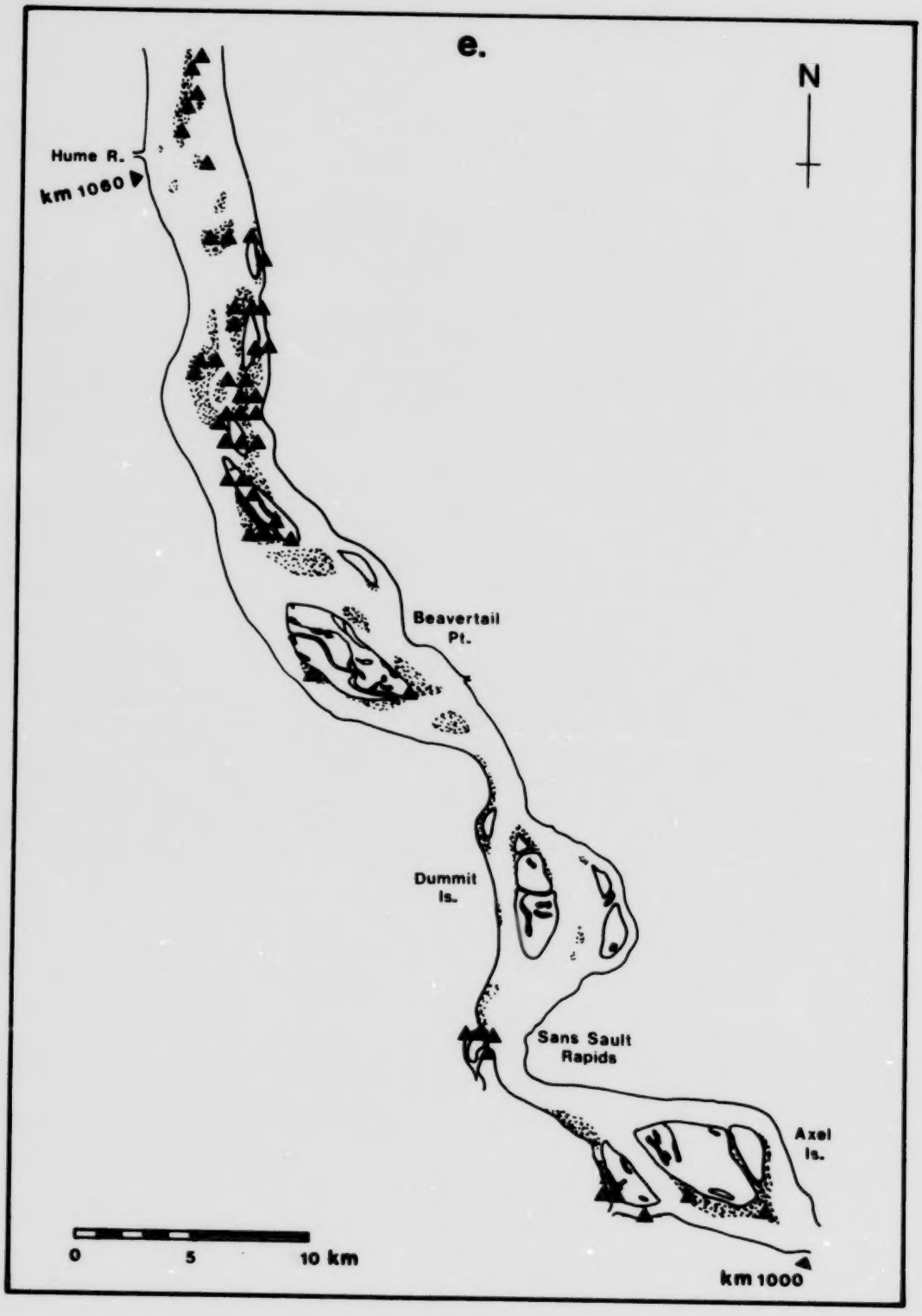

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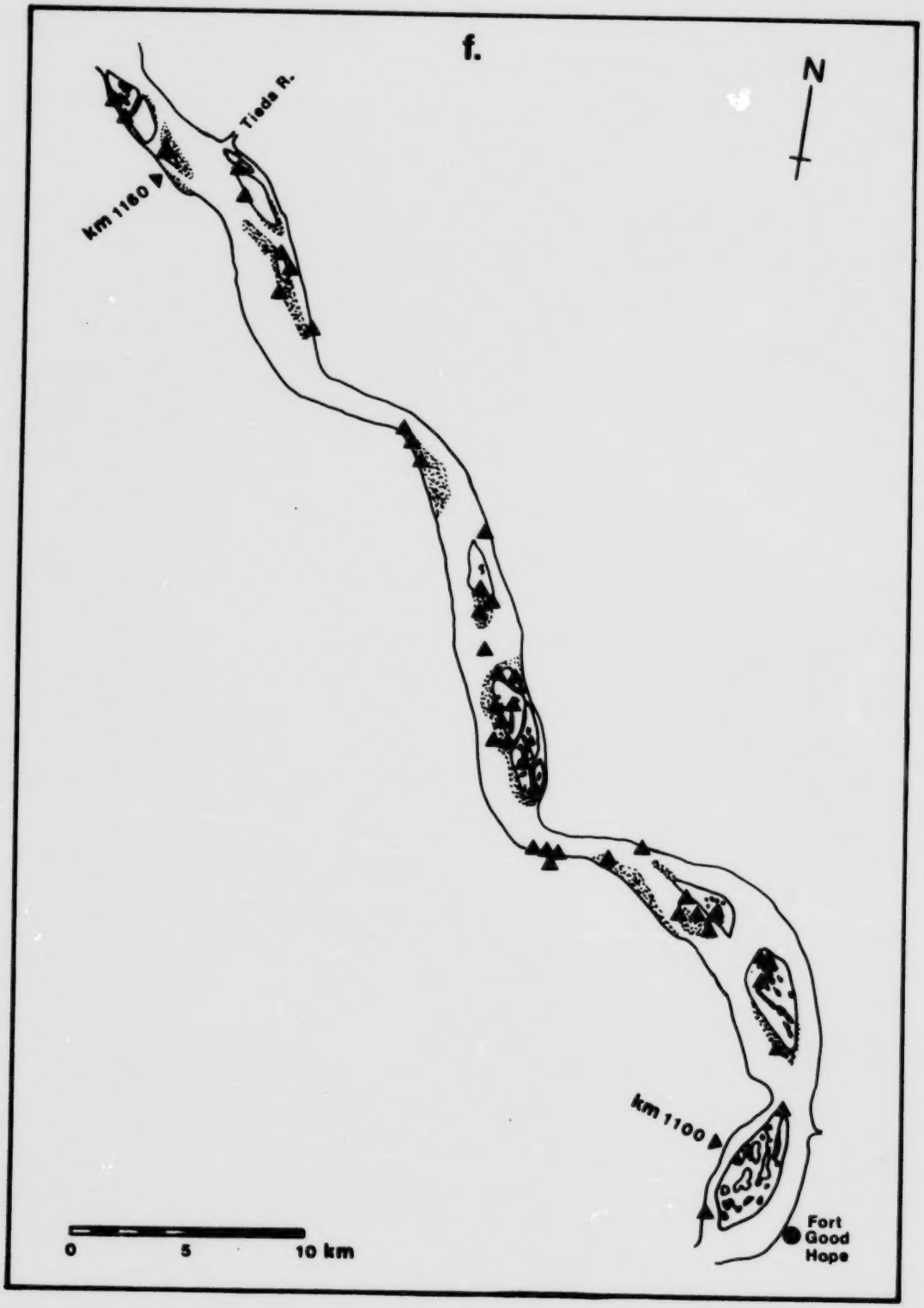

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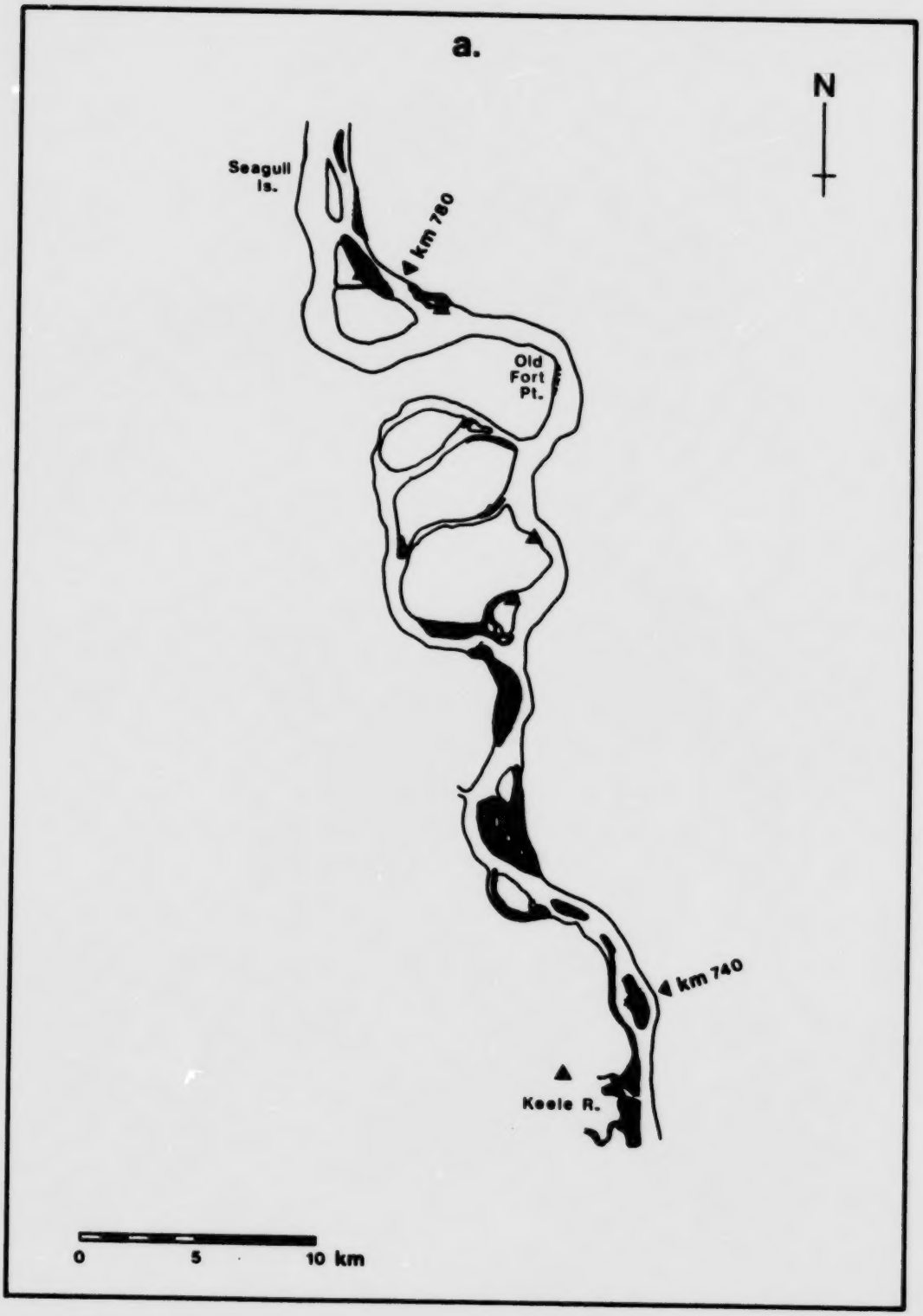


Figure 5. Distribution of preferred snow goose staging habitat (red) in the study area in relation to snow goose sightings (triangles).

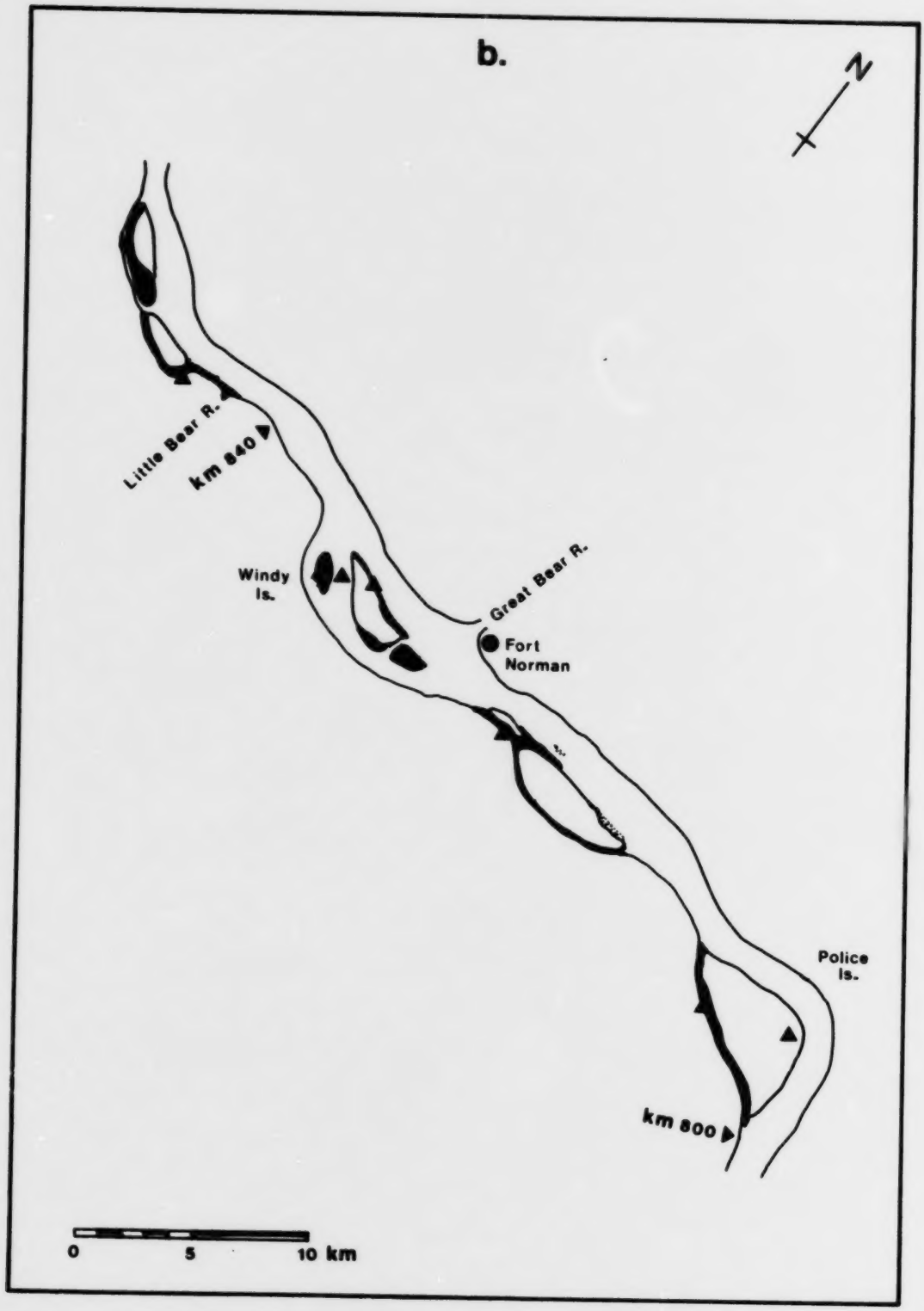
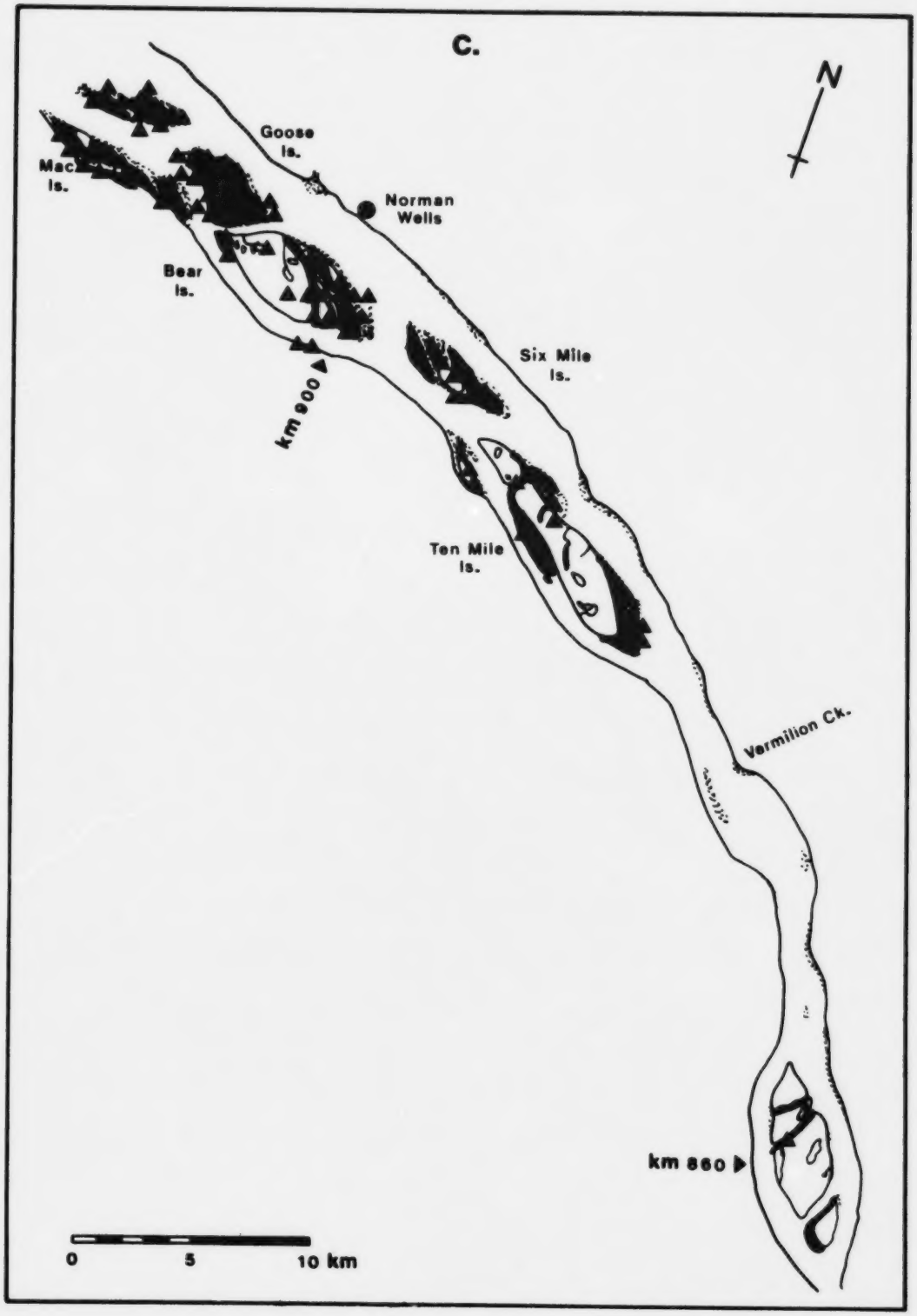


Figure 5. (cont'd)



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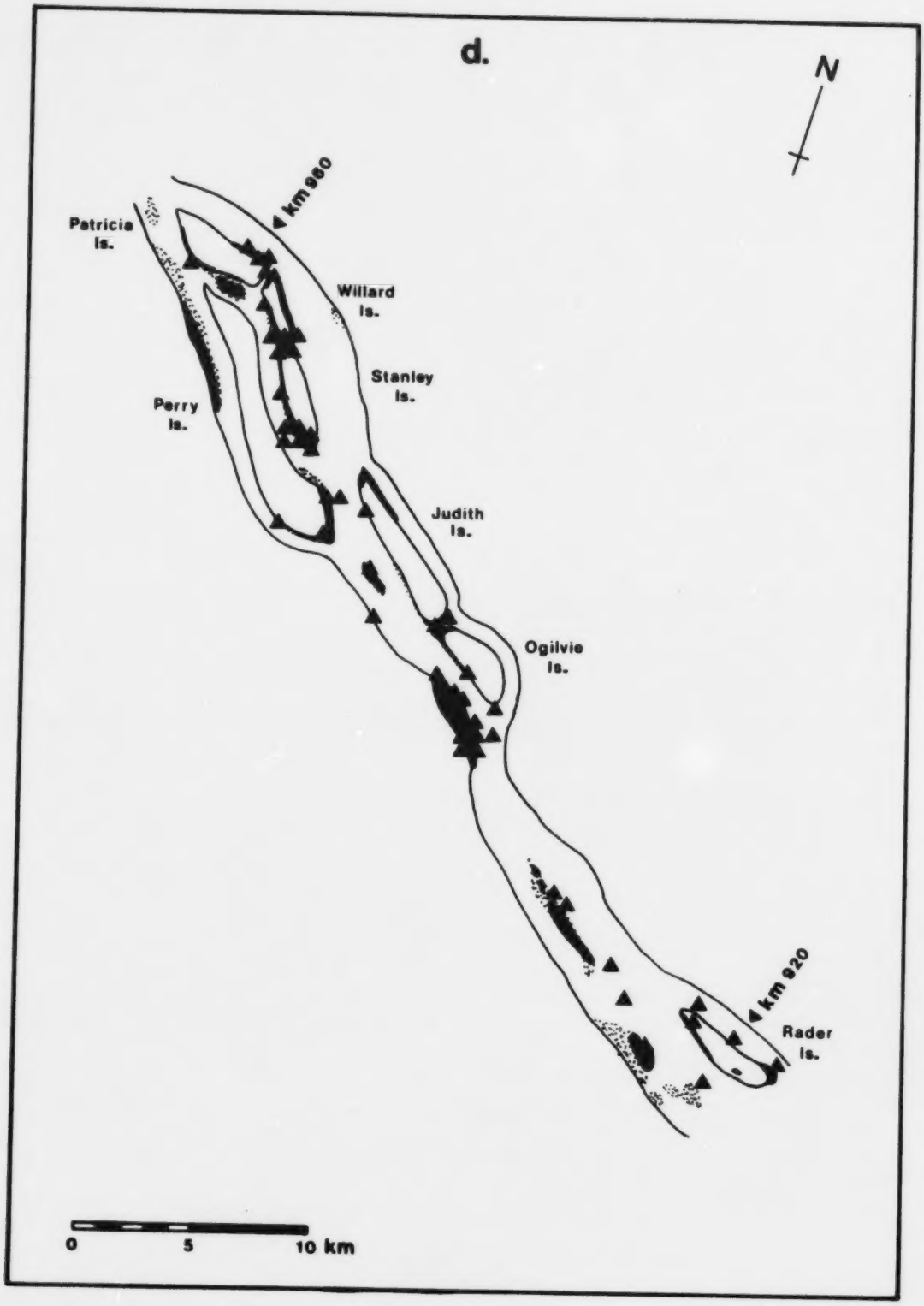

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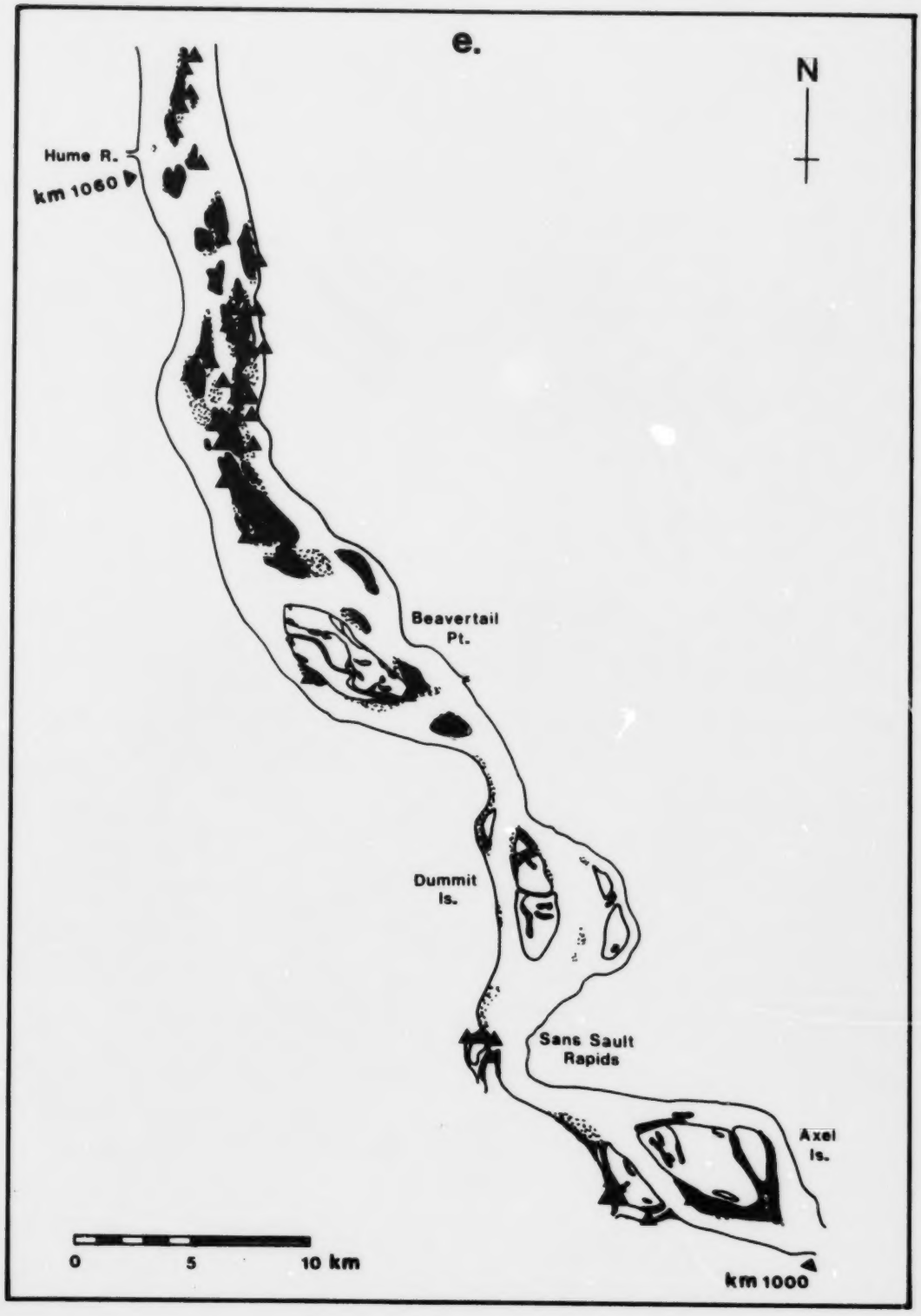

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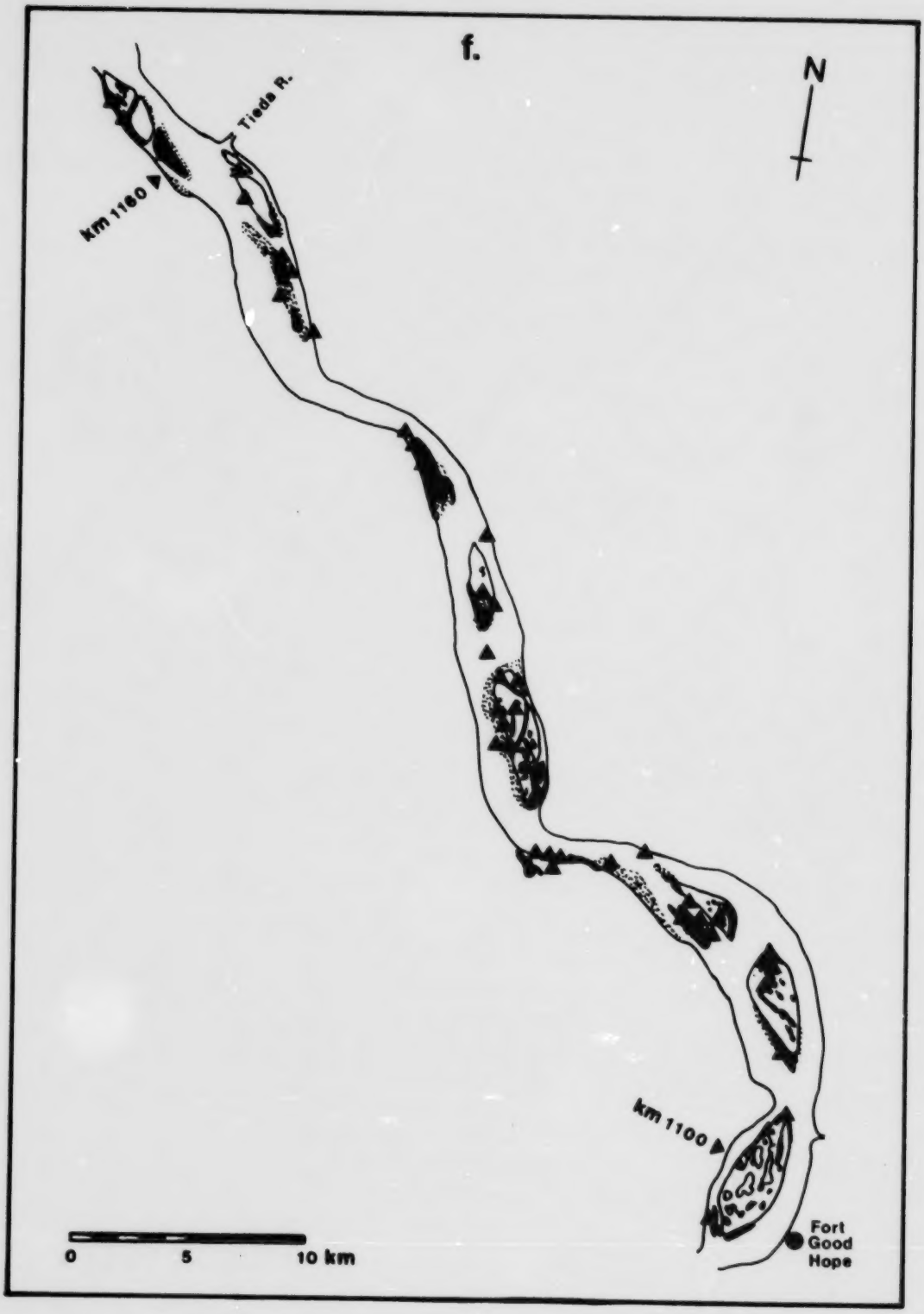


Figure 5. (cont'd)

Desirable habitat is present in the most upstream reach of the study area, between Keele River and the complex of large islands south of Old Fort Point (Figure 5a). However, downstream of Old Fort Point, good distribution of favourable habitat is not encountered to much extent until the Norman Wells area where it extends from Ten Mile Island to Mac Island (Figure 5c). Except for the area of habitat along the shoreline to the west of Ogilvie Island, favourable habitat in the Ogilvie Island - Patricia Island reach is largely limited to the tips of, and shallow water areas between, the islands (Figure 5d). Downstream, good habitat is absent until downstream of Beavertail Point where a collection of low-lying islands extends as far as the Hume River inflow (Figure 5e). Although not as extensive, further desirable habitat is distributed in the most downstream reach below Fort Good Hope (Figure 5f).

4.4 Spring Open Water Distribution

In many cases, air photo coverage (courtesy of Esso) of the Mackenzie River at breakup was discontinuous and therefore, could not be used to map spring open water conditions in a consistent manner. Therefore, a technique developed by J. Moir (pers. comm.) of Esso was used to map the "expected" distribution of open water areas. The technique is based on the assumption that, during the winter, the Mackenzie River is completely frozen over with ice having an average thickness of 1.5 m (Kamphuis and Moir 1983). Wherever the river is less than 1.5 m in depth, including the shores of islands and shoal areas, bottomfast ice develops during the winter. As a result of slowly falling water

levels, hinge cracks develop between the floating ice sheet and the bottomfast ice. In the spring, increased river discharge slowly raises the floating ice sheet which eventually breaks away from the bottomfast ice along the hinge cracks as it rises, and water floods the bottomfast ice. From the air, this gives the appearance of narrow shore leads. Ice melting occurs primarily by candling and, since the albedo is greater in shallow waters, stranded ice melts earlier than ice floating in deeper waters. A more thorough explanation of the process of ice melting on the Mackenzie River is given by Kamphuis and Moir (1983).

Figure 6 was derived by shading those portions of the river having a depth of 1.5 m or less. The maps were prepared using hydrographic maps published by the Hydrographic Service of Fisheries and Oceans Canada. Figure 6 shows, therefore, the areas where ice leads and flooded bottomfast ice are likely to appear first in the spring and the expected pattern of open water as breakup progresses. The actual appearance of leads and actual breakup pattern varies from year to year, depending on factors such as ice thickness and strength, air temperature and wind (Kamphuis and Moir 1983).

From Figure 6, we can conclude that open water is likely to occur every year upstream of Old Fort Point, near Fort Norman, between Ten Mile Island and Patricia Island, between Sans Sault Rapids and Hume River and sporadically downstream of Fort Good Hope. The probability for extensive open water to be present is highest between Six Mile

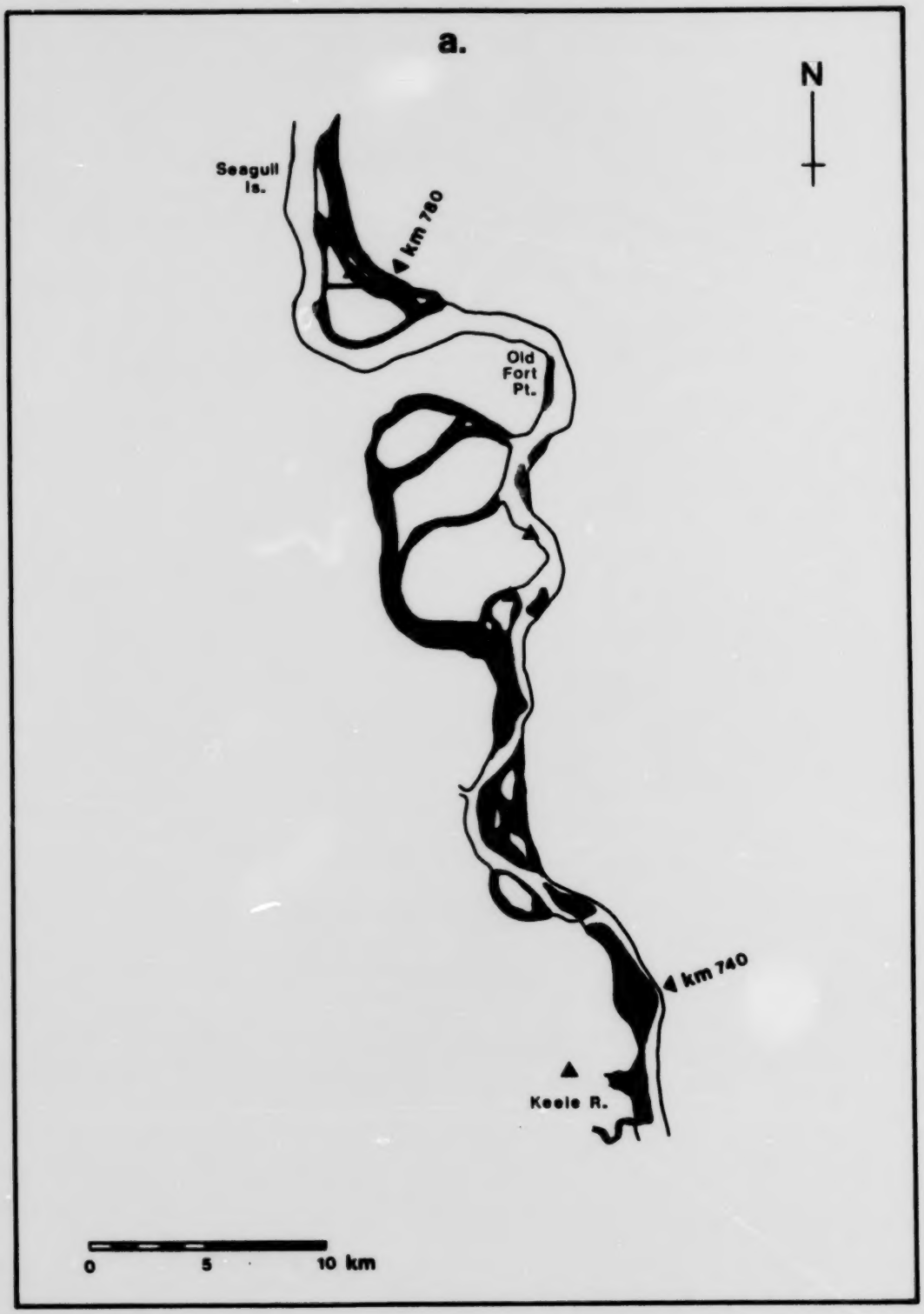
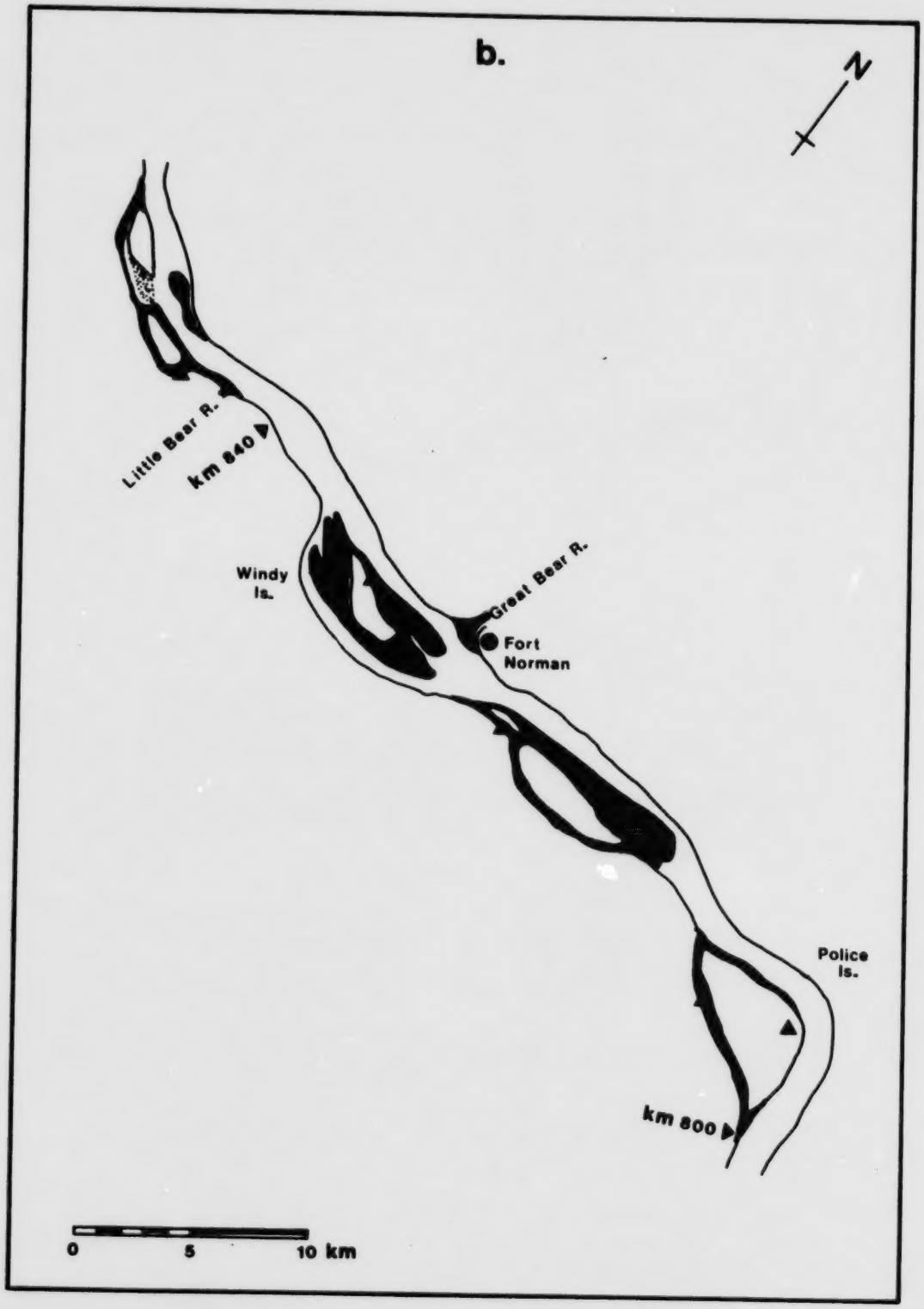


Figure 6. Locations in the study area where ice leads, flooded bottomfast ice and open water (blue) are most likely to appear in the spring in relation to snow goose sightings (triangles).



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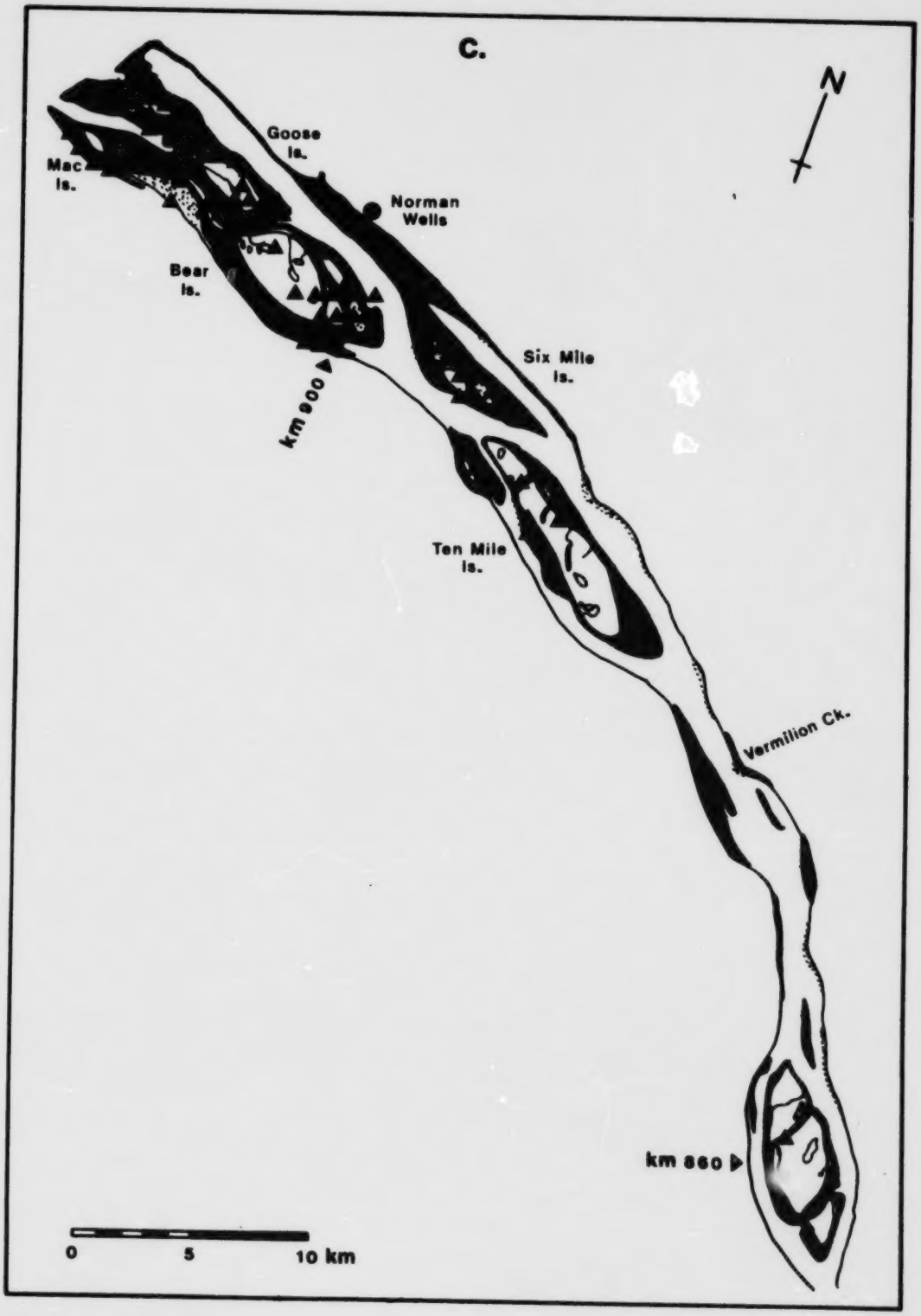

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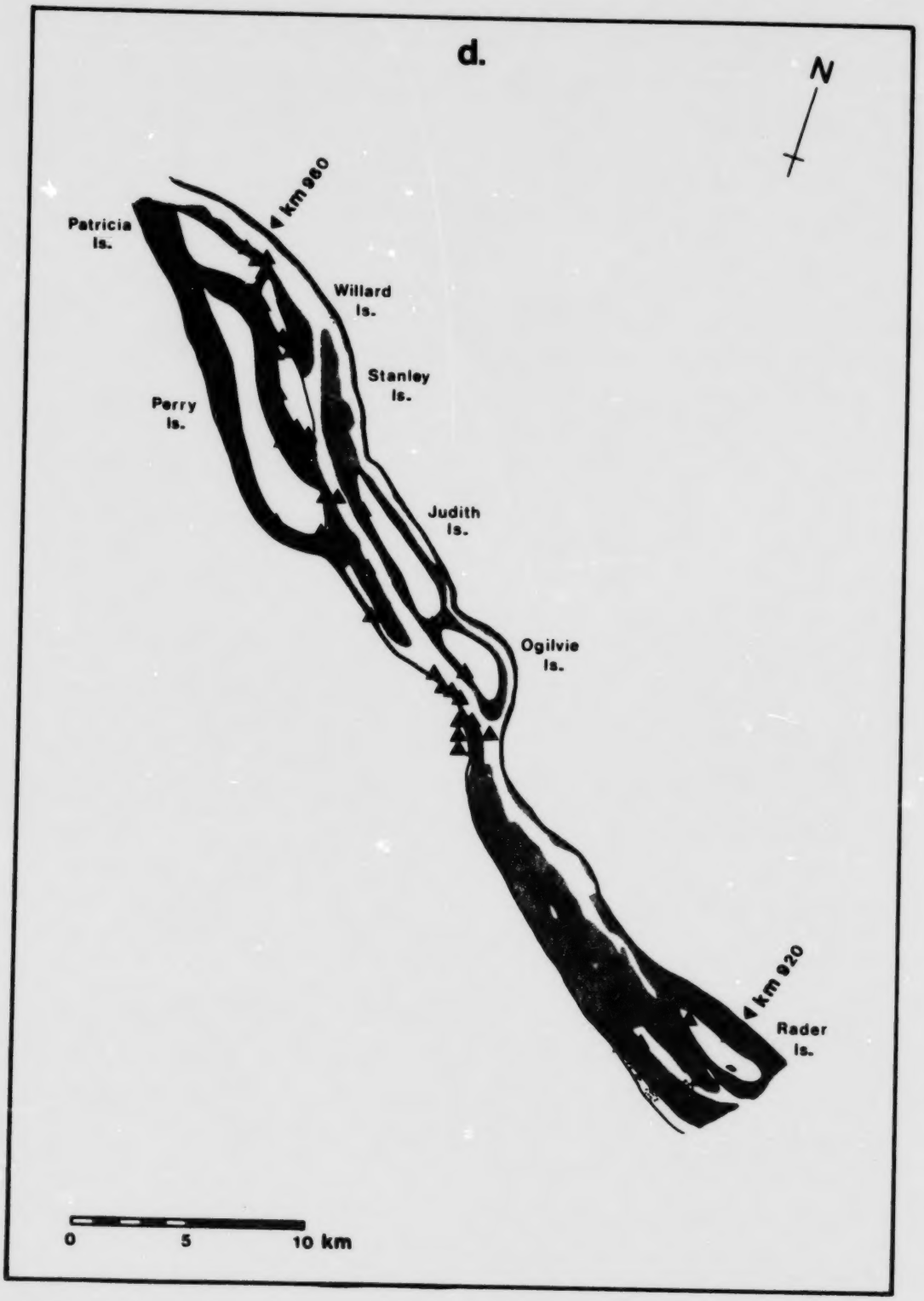

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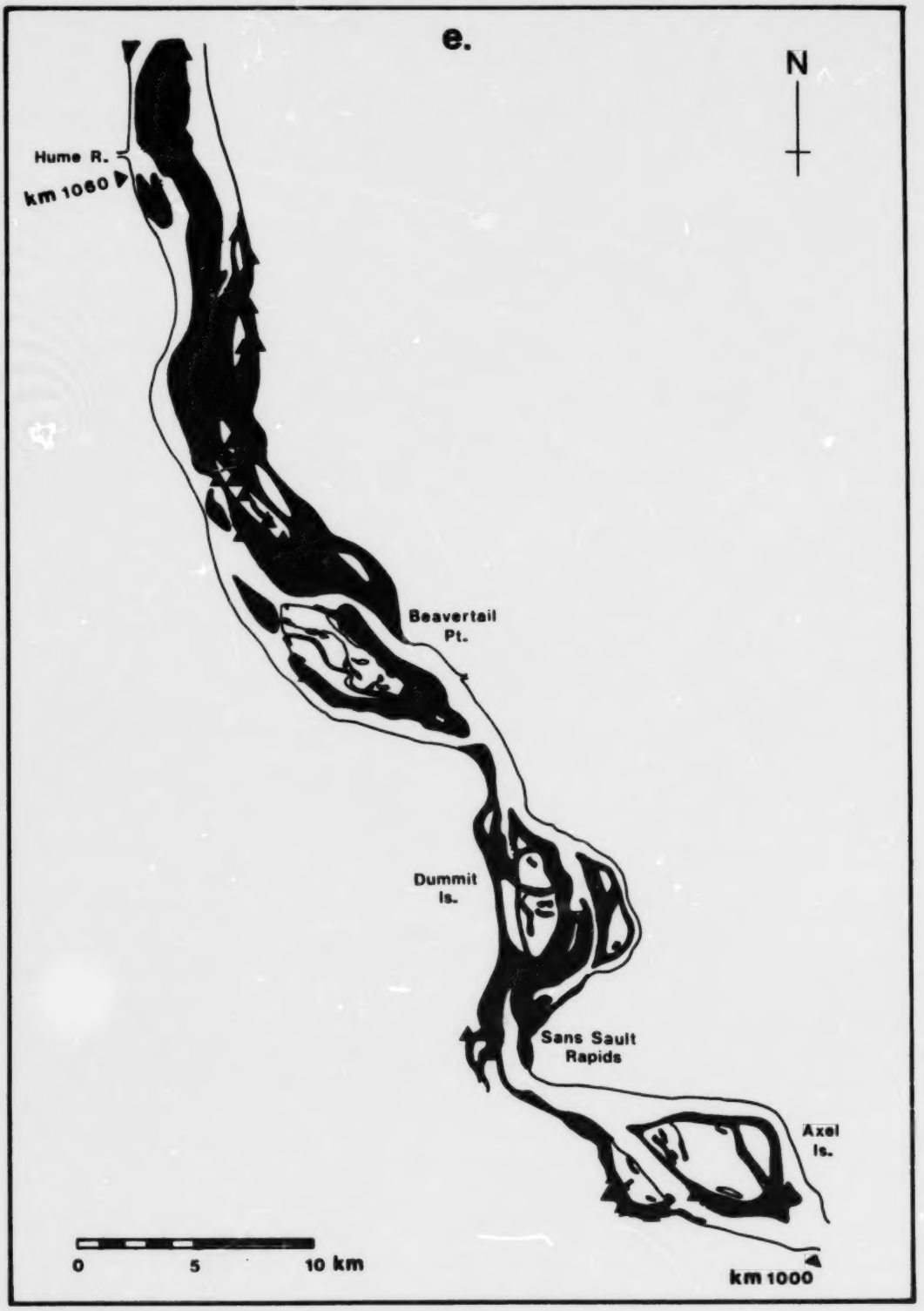

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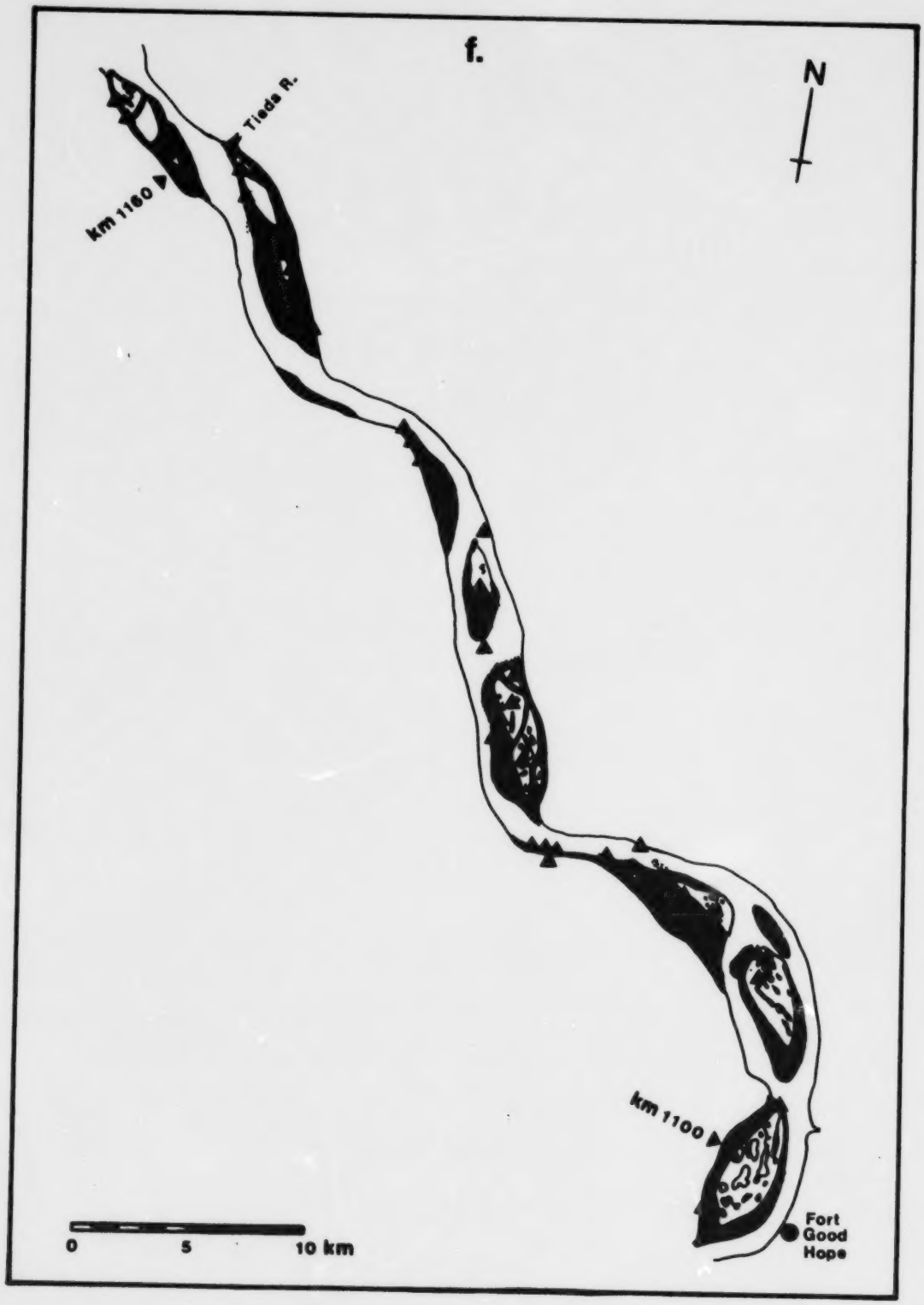


Figure 6. (cont'd)

Island and Patricia Island and between Beavertail Point and Hume River.

4.5 Snow Goose Distribution in Relation to Habitat Availability and Open Water Distribution

Figure 7 displays spring snow goose use in relation to the distribution of preferred staging habitat and open water areas (i.e. ice leads, cutoffs, ice-free ponds and open water) on the Mackenzie. The relationship between snow goose use, habitat and open water is discussed in the following section (section 5).

4.6 Important Snow Goose Staging Areas

Figure 8 shows the locations of staging areas which are considered to be the most important to snow geese based on the snow goose use data. Habitat areas located closest to Norman Wells (downstream as far as Patricia Island) should receive priority for protection in the event of an oil spill originating from activities in the Norman Wells area.

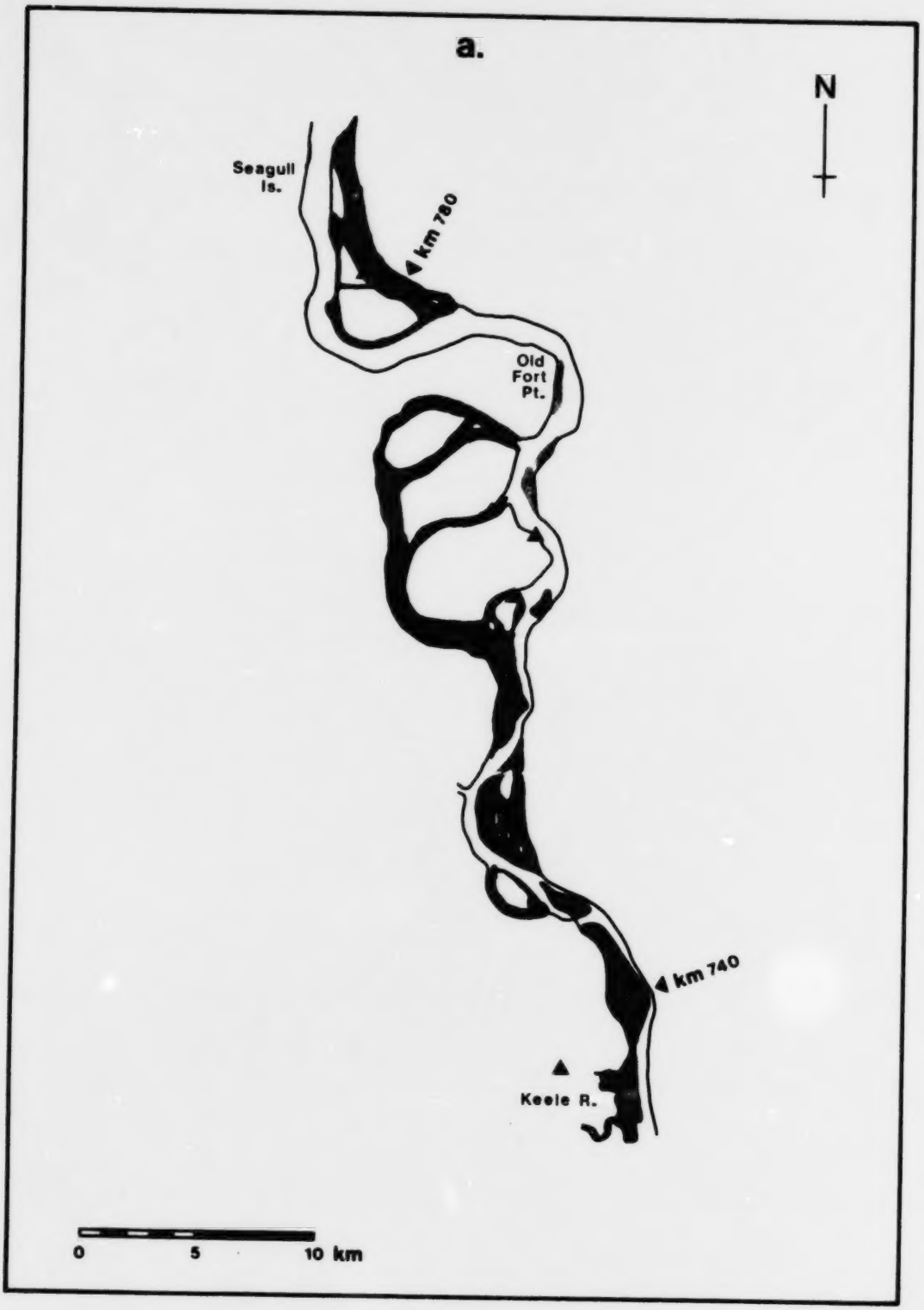
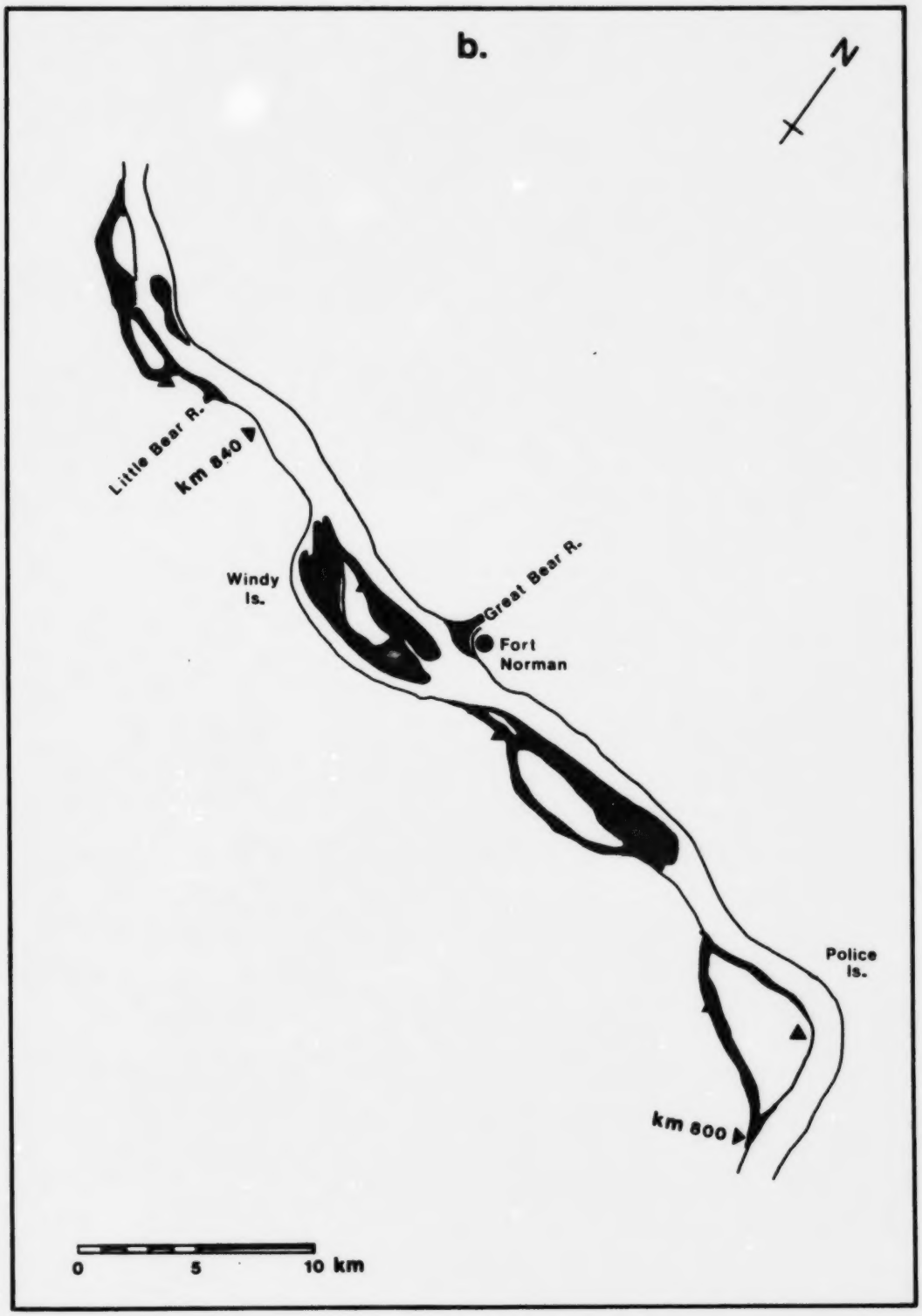


Figure 7. Locations of snow goose sightings (triangles) in relation to staging habitat (red) and open water (blue) distribution.



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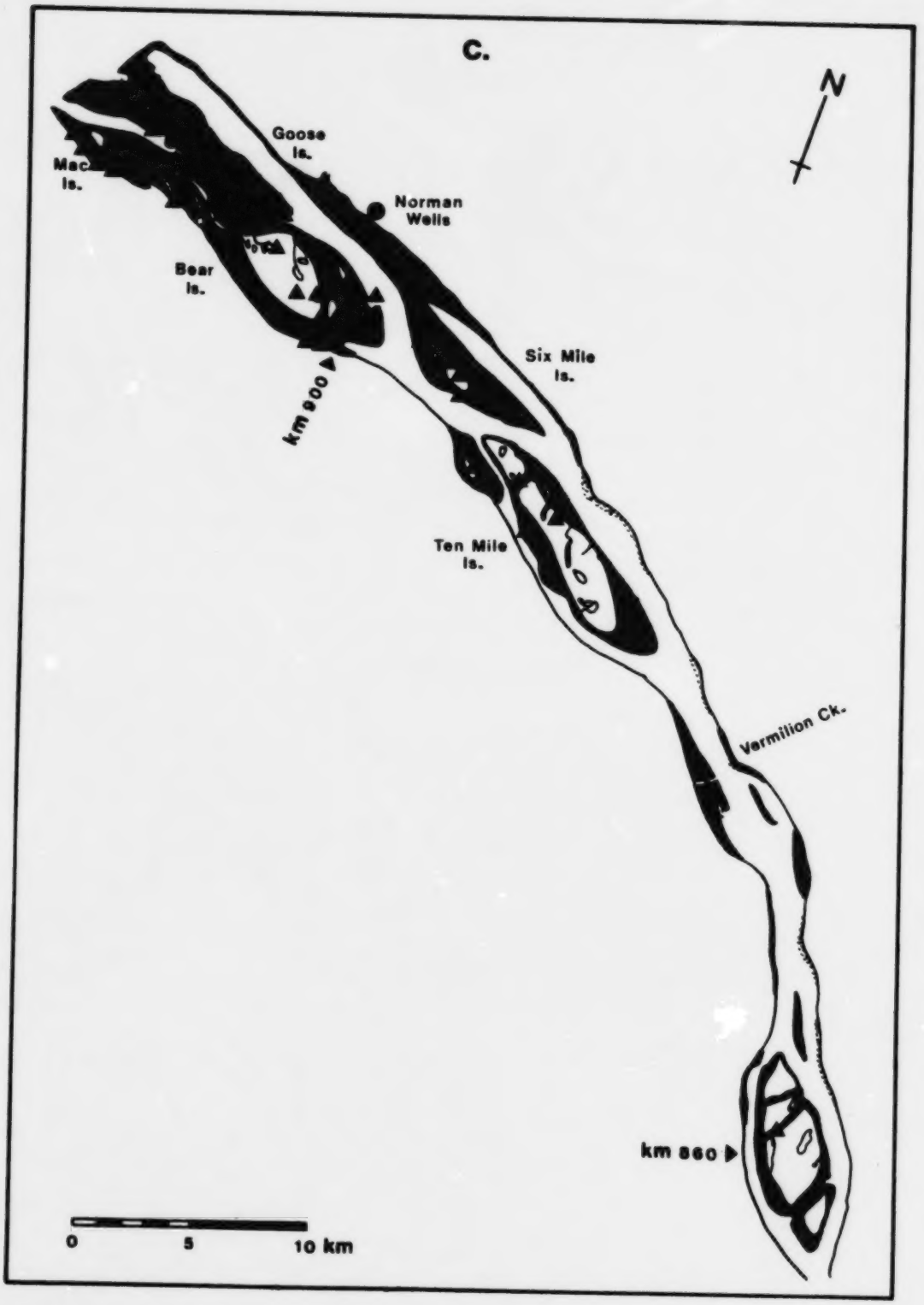

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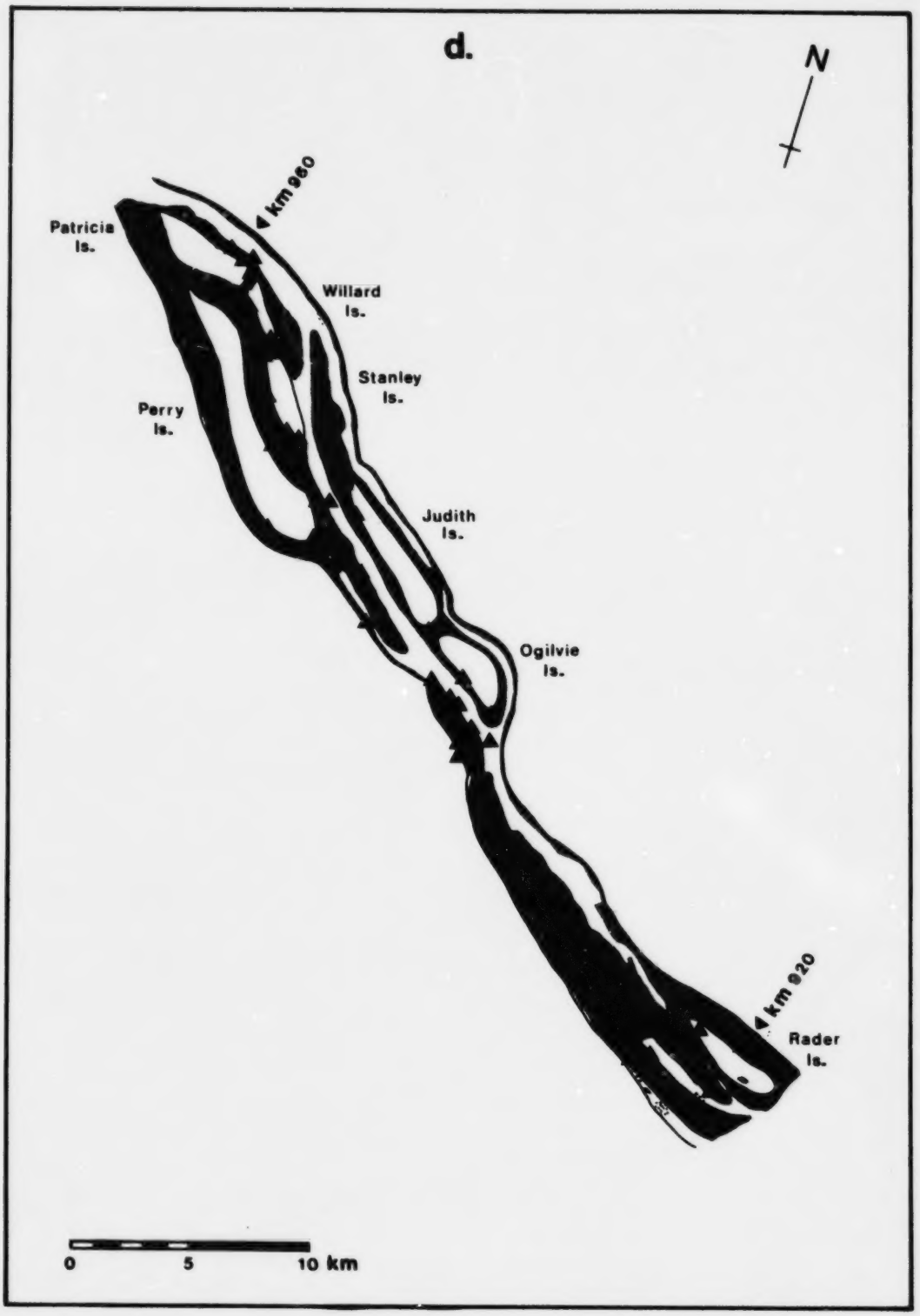

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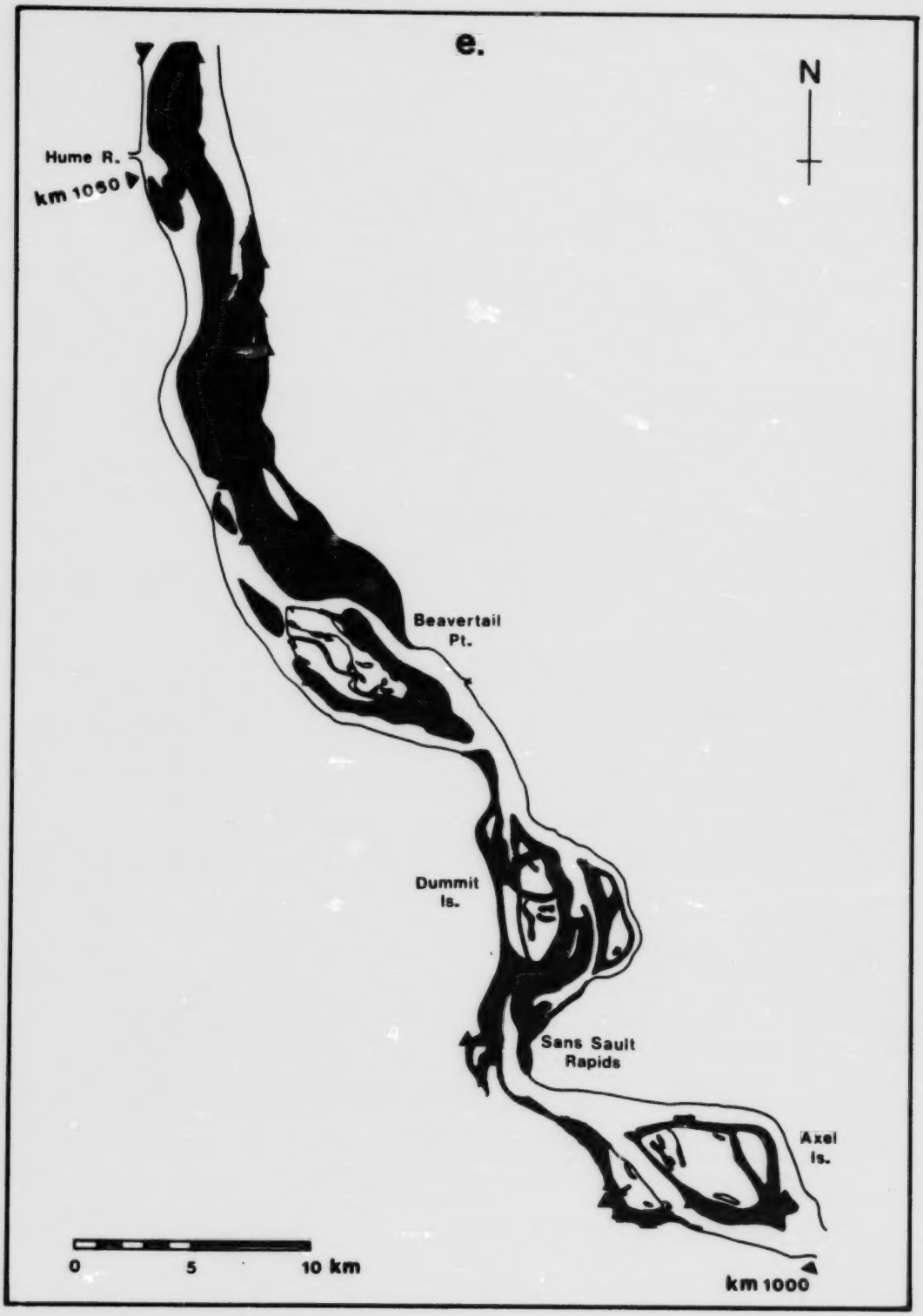

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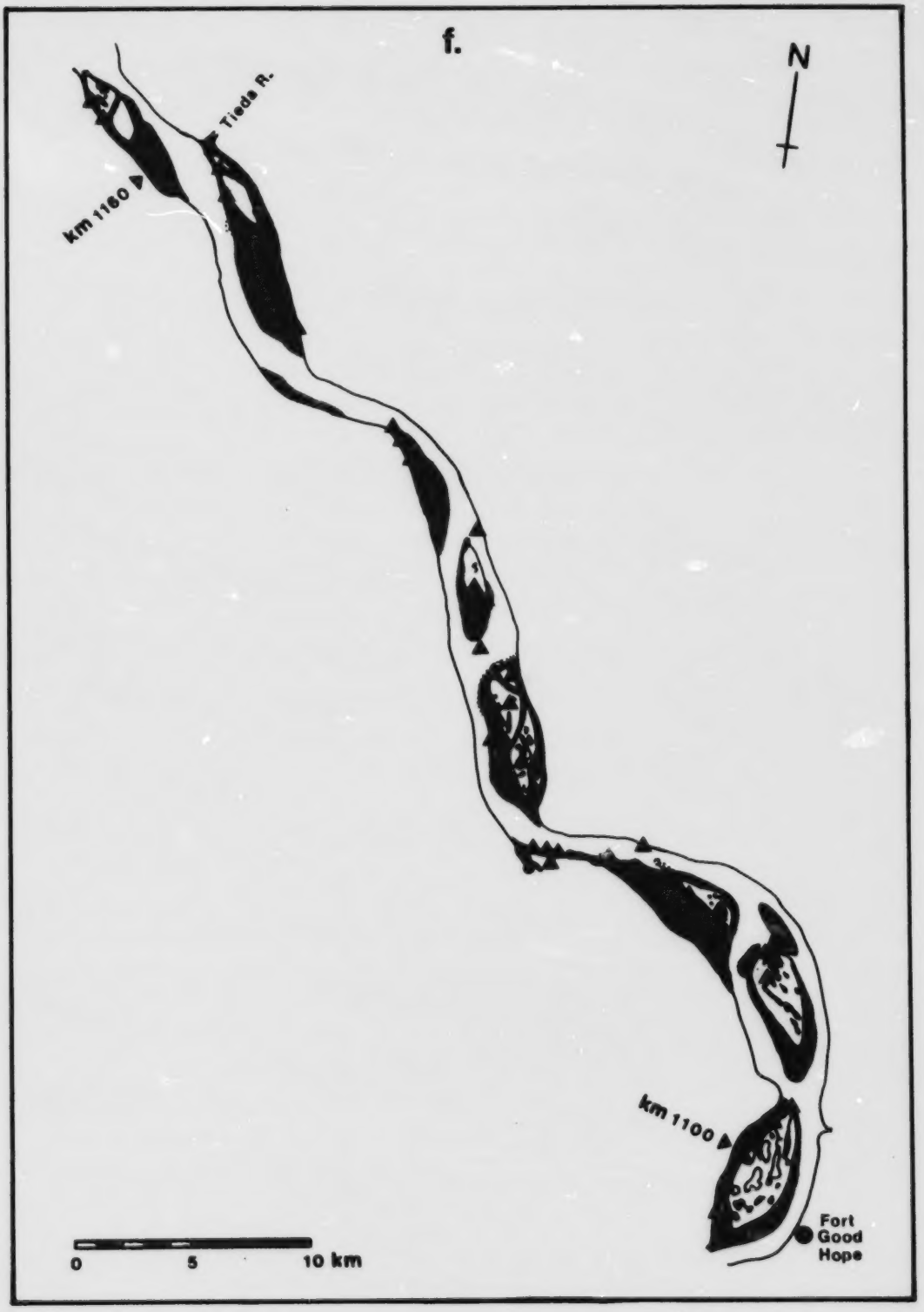

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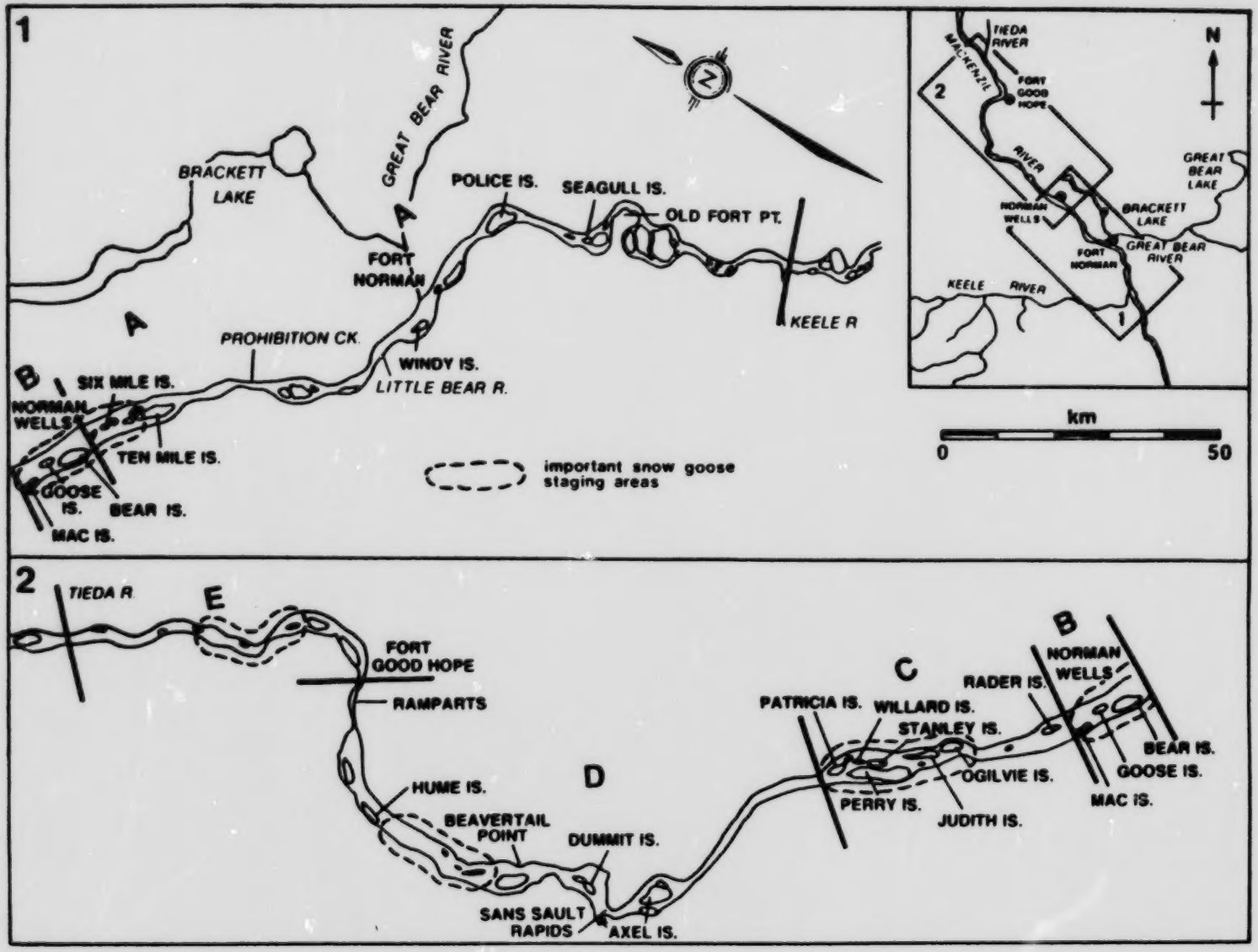

Figure 8. Locations of important snow goose staging areas in the study area.

5. DISCUSSION

5.1 Factors Affecting Snow Goose Distribution

Many factors influence the extent to which snow geese use specific habitat areas along the Mackenzie River during spring staging. Figure 9 diagrams how different environmental conditions might affect the distribution of snow geese at a given location on a given day during spring migration. The following sections discuss the interplay of some of these factors.

5.11 Habitat and Open Water

The influence of some of the environmental factors shown in Figure 9 can be evaluated using information already presented in section 4. Availability of suitable terrestrial habitat (factors 1,2 and 3 in Figure 9) in the study area is shown on the maps of Figure 5. The expected distribution of ice leads, flooded bottomfast ice and ice-free areas (factors 4 and 5) is indicated in Figure 6.

Figure 7 shows spring snow goose use of the Mackenzie River (in the study area) in relation to habitat availability and open water distribution. This figure, therefore, illustrates the interaction between factors 1 to 5 and snow goose distribution. As noted in section 4, snow geese appear to have an affinity for reaches between Ten Mile and Mac Islands (Figure 7c), between Ogilvie and Patricia Islands (Figure 7d), between Beavertail Point and Hume River (Figure 7e), and for some areas downstream of Fort Good Hope (Figure 7f). Poston *et al*. (1973) included the Norman Wells, Beavertail Point-Hume River and Fort Good Hope-Tieda River areas as being

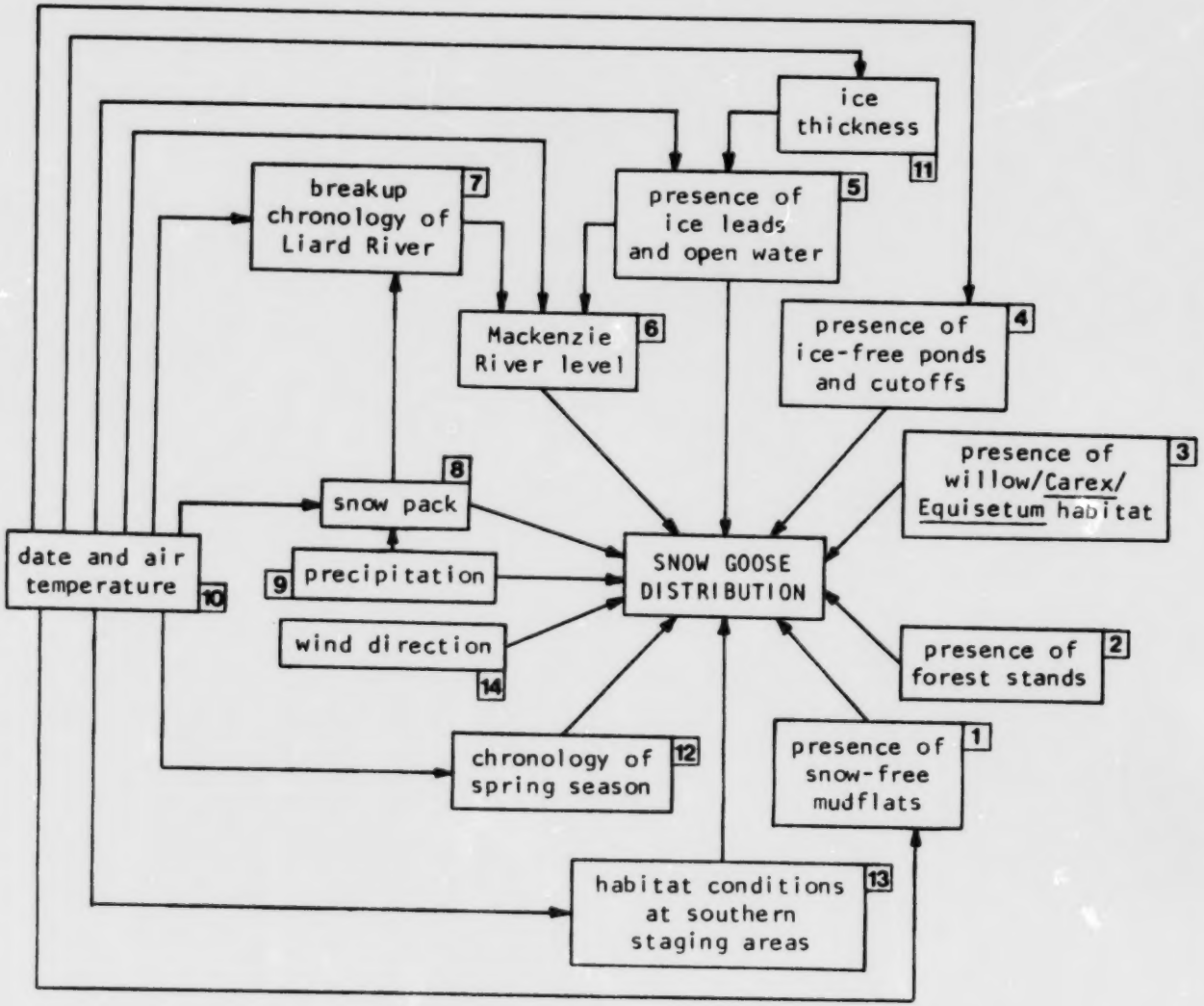

Figure 9. Factors influencing spring distribution of snow geese on the Mackenzie River and their interrelationship.

"critical concentration areas" for spring migration.

Each snow goose observation shown in Figure 7 was examined to determine the type of habitat with which it was associated. Snow geese were found to be associated with four distinct habitat types:

a) islands consisting of mudflats (unvegetated or sparsely-vegetated) or having sedge/willow growth, and island shorelines and river bank consisting of mudflats or having sedge/willow growth;

b) shallow-water areas located between islands or between islands and the river bank;

c) ice-free ponds, cutoffs and lakes located on islands adjacent to, or within, forest stands (spruce and/or poplar); and

d) shorelines and river bank areas directly adjacent to forest stands.

Each snow goose observation was placed in one of the four categories (Table 6). Over the five years for which site-specific data was available, an average of 81 percent of snow geese were associated with mudflat/sedge/willow habitats (category a) above). In contrast, a relatively small proportion of the observations were associated with habitat adjacent to forested areas (factor 2). Presence of forest stands appears, then, to inhibit the use of adjacent habitat. Habitat category a) was mapped in Figures 5 and 7. In their 1982 investigation of habitat selection by staging waterfowl along the Mackenzie River, Ealey and Penner (1983) found almost 34 percent of

Table 6. Habitats associated with snow goose observations made in 1972, 1980, 1981, 1983 and 1984, as shown in Figure 7.

Habitat	No. of observations					
	1972	1980	1981	1983	1984	Total
Mudflat/sedge/ willow islands and shorelines	80 (82) [a/]	19 (83)	11 (92)	8 (89)	79 (78)	197 (81) [c/]
Shallow water areas between land masses	2 (2)	2 (9)	– [b/]	1 (11)	12 (12)	17 (7)
Waterbodies on forested islands	8 (8)	1 (4)	–	–	2 (2)	11 (5)
Forested landmass shorelines	8 (8)	1 (4)	1 (8)	–	8 (8)	18 (7)
Total	98	23	12	9	101	243

a/ % of total observations made that year

b/ no observations

c/ % of observations (all years)

the snow geese to be associated with sparsely-vegetated mudflats. Almost 17 percent were observed using willow habitat; use of other habitat types was less than 10 percent in each case.

Figure 7 appears to indicate that snow geese are attracted to areas of the study area where preferred habitat is available and where there is also a good probability of ice leads, flooded bottomfast ice and/or open water being present. The two highest use areas, downstream of Six Mile Island and Beavertail Point, certainly have well-interspersed habitat and open water distribution. Further examination of Figure 7 and consideration of the relative importance of these two factors leads to the conclusion that habitat availability is the key factor influencing snow goose use of a given reach. Presence of ice leads or open water in the Mackenzie River with no adjacent favourable habitat present is not attractive to snow geese since the water itself has no real value. For example, the series of channels upstream from Old Fort Point (Figure 7a) does not generally receive heavy use by snow geese even though open water is usually abundant.

Habitat selection data presented by Ealey and Penner (1983) seems to concur with the conclusion that the presence of open water is not a major factor determining snow goose use. Only 3.1 percent of the snow geese observed in 1982 were located at leads in the river channel; only 0.9 percent were associated with shoreline leads. Meltwater pools situated on the ice attracted 0.1 percent of the geese while meltwater pools positioned on mudflats were used by only 0.8 percent.

Use of the river ice for resting has been noted by R. Webb Environmental Services Ltd. (1983, 1984) and Ealey and Scott-Brown (1984). Ealey and Penner (1983) reported that 10.2 percent of the geese observed in 1982 were located on the ice. In the present study, it was noted that geese tended to rest on ice in proximity to shoreline leads which bordered attractive habitat located on Goose Island.

In general, the formation of shoreline leads is directly related to the presence of habitat types preferred by snow geese. Low-lying alluvial flats, and islands or mainland areas vegetated with early-successional species (e.g. sedges and willows), all have low-gradient shorelines which gradually dip below the river level. These land masses will, therefore, have wide margins of bottomfast ice which will become flooded as the river level (factor 6) rises and causes the floating ice sheet to break away from the bottomfast ice (Kamphuis and Moir 1983). In addition, dust is picked up by wind action on the mudflats and deposited on the adjacent bottomfast ice. Presence of this wind-blown dust on the ice also encourages early melting and degradation of the bottomfast ice (T. Barry, pers. comm.). For these reasons, shoreline leads and flooded bottomfast ice tend to be associated with the early-successional habitat favoured by the staging geese.

It is evident that the availability of attractive staging habitat along the Mackenzie River is the major reason for its importance to snow

geese during spring migration. Virtually no other suitable habitat, free of snow and ice, exists on either side of the river. The only significant off-river habitat area between Mills Lake (at the western end of Great Slave Lake) and the Mackenzie Delta is Brackett Lake.

5.12 Mackenzie River Water Levels

The timing of river level rise in the spring, resulting in shore lead development, is directly related to the chronology of breakup of the Liard River (MacKay and Mackay 1973), identified as factor 7 in Figure 9. A number of factors, such as depth of snow (factor 8) and ice, overwinter and spring precipitation (factor 9) and air temperature (factor 10), determine the timing of Liard River breakup. The term "breakup" is defined differently by various authors. In this report, the definition used by Ealey and Penner (1983) is adopted: the point in time when in situ ice first moves. Therefore, breakup at Norman Wells occurs on the date when floating ice sheets first start moving away from bottomfast and grounded ice. Kamphuis and Moir (1983) state that the first major ice movement at Norman Wells, in relatively solid ice with straight shore leads, takes place during a rapid rise in water level and at an approximate elevation of 44.5 m.

Figure 10 shows the timing of breakup at Norman Wells in relation to river flows in 1972 and river levels in 1980, 1981, 1983, and 1984. In 1972, breakup occurred before peak flows had been reached. In 1981, breakup coincided with a rapid rise in water levels whereas, in 1980 and 1984, breakup occurred while water levels were subsiding. Breakup in 1983 occurred at the time of peak water levels. From these

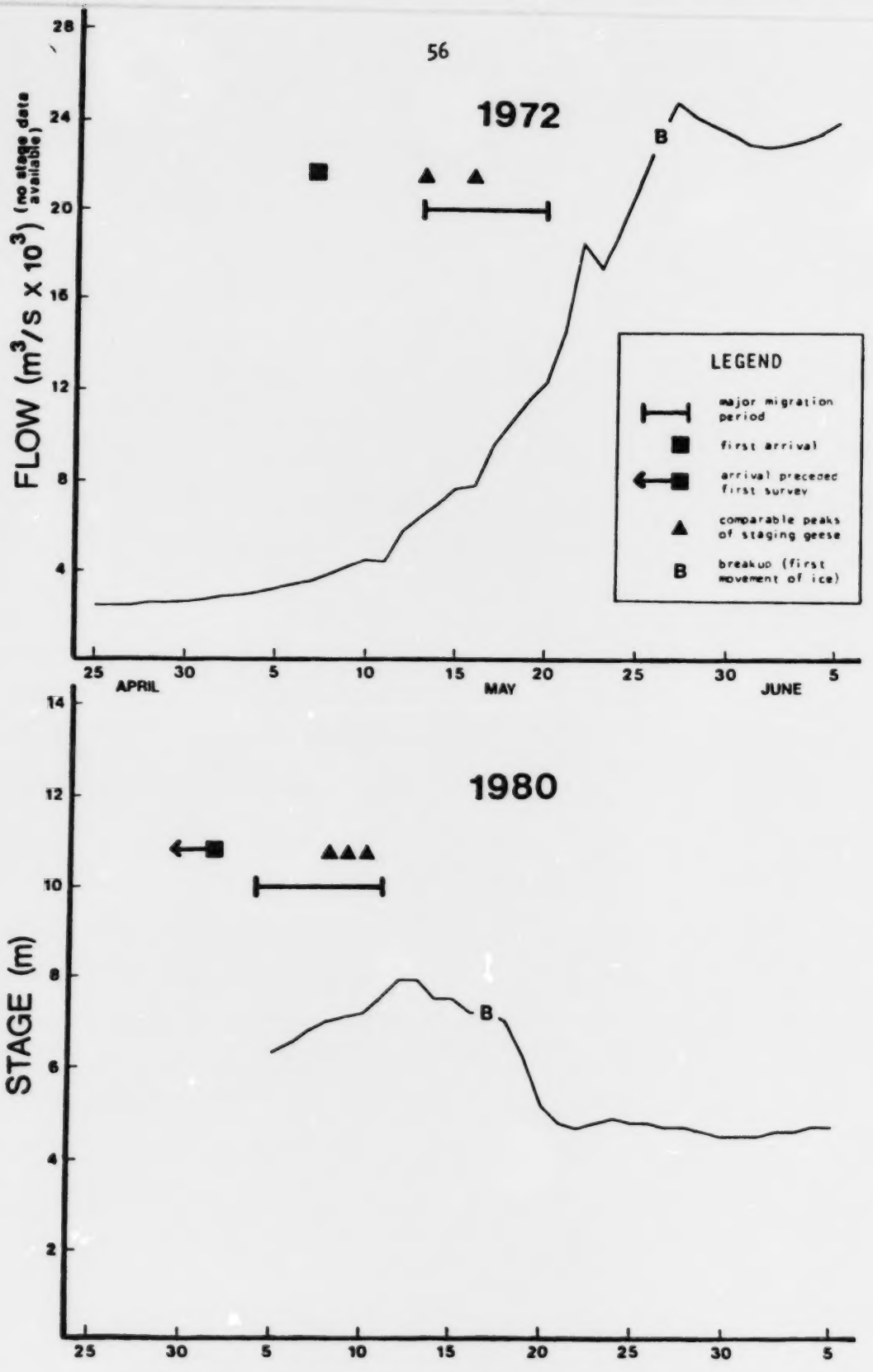

Figure 10. Mackenzie River flows in 1972, and levels in 1980, 1981, 1983, and 1984, in relation to snow goose migration and breakup at Norman Wells.

Sources: water data - Inland Waters Directorate; breakup dates - Esso Resources Canada; goose data - 1972,1980,1981,1983: Ealey and Scott-Brown (1984), 1984: this study.

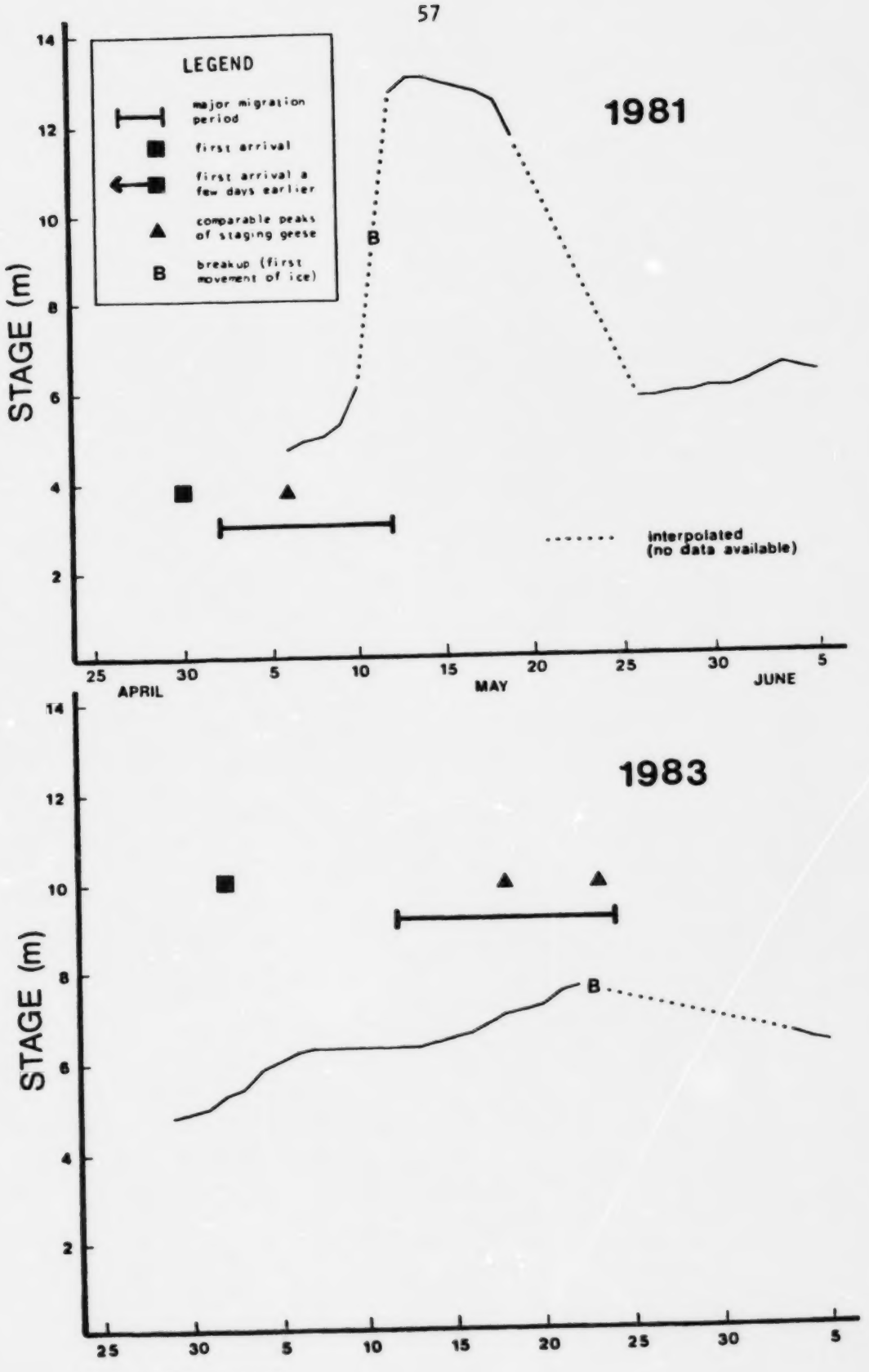

Figure 10 (cont'd)

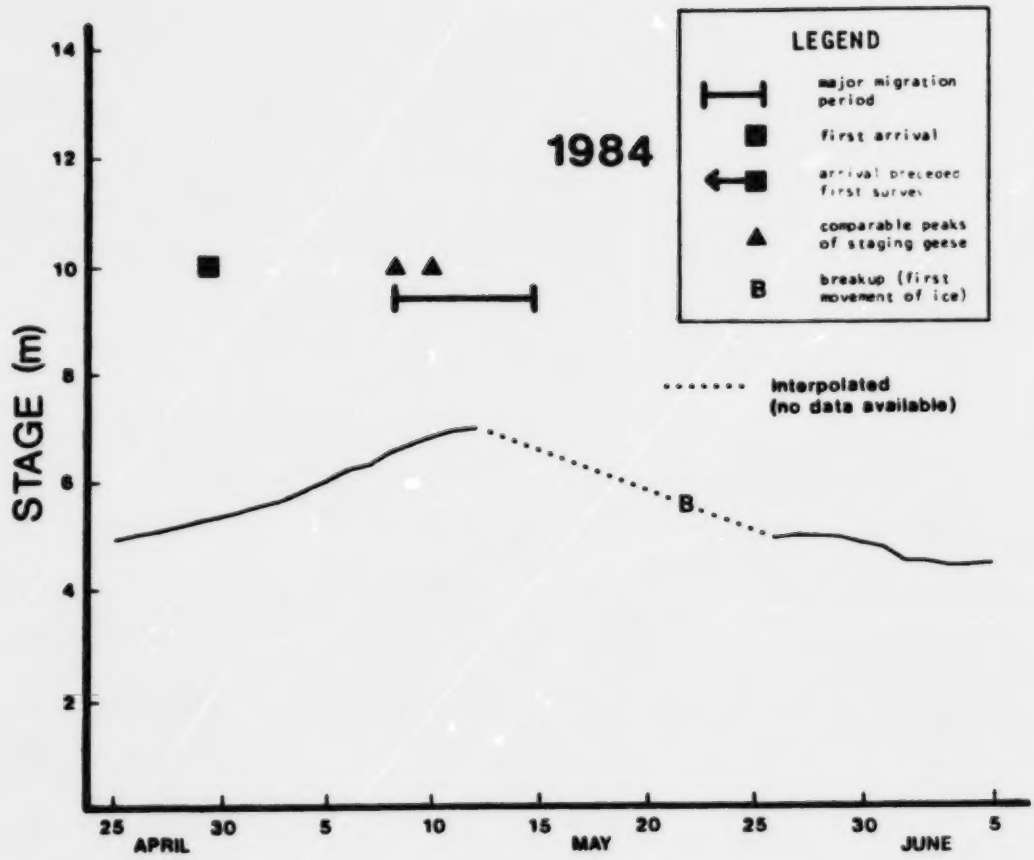

Figure 10 (cont'd)

observations, it appears that breakup does not necessarily occur during the period of water level rise unless that rise is rapid, as in 1981. A more gradual rate of increase appears to delay breakup and other factors, such as ice thickness (factor 11) and extent of ice deterioration, probably determine the onset of breakup under those conditions.

In 1972 and 1980, staging snow goose flocks had already departed from the Norman Wells area more than five days prior to breakup (Figure 10). Snow goose migration and breakup occurred earlier in 1980 than in 1972. In 1981 and 1983, the departure of snow goose flocks from the Norman Wells area coincided with breakup even though breakup in 1983 occurred more than 10 days later than in 1981. Snow goose surveys ended in 1984 prior to breakup and, therefore, the relationship between breakup timing and snow goose migration is not known for that year.

Ealey and Penner (1983) related the basic snow goose migration pattern to reductions in habitat availability caused by rising water levels. As noted earlier, breakup of the Liard River causes an increase in levels on the Mackenzie. Water levels can also be dramatically increased as a result of ice jamming (i.e. the stopping of ice movement downstream). The formation and release of ice jams on the Mackenzie is described in detail by Kamphuis and Moir (1983) and, therefore, will not be discussed here. The dramatic effects of ice jams were demonstrated during breakup in 1981. Extremely high temperatures had

resulted in breakup proceeding very rapidly from Fort Simpson to Rader Island (just downstream from Norman Wells). Temperatures dropped suddenly on the night of May 10-11 and, although breakup occurred at Norman Wells on May 11, breakup stopped at Rader Island. An ice jam formed, the river level rose and by the next day Goose Island was totally submerged except for Esso's two drilling pads (R. Webb Environmental Services Ltd. 1983). The ice jam remained in place for a full seven days before it released. Needless to say, as water levels rose, mudflats, sedge/willow, and finally willow habitat, upstream of Rader Island became flooded. With favourable habitat completely removed from use, almost no snow geese remained in the area (Figure 10).

In 1980, water levels were high for an unusually long period before breakup. Mackenzie River waters were already flooding the willow zone on Goose Island on May 9 (R. Webb Environmental Services Ltd. 1980). The willows remained flooded until after May 19. In contrast, water levels at Norman Wells rose only gradually in 1983 until breakup occurred on May 23. As a result, good goose habitat was generally available along island edges for a relatively long period of time before flooding occurred at breakup (Ealey and Scott-Brown 1984). Similarly, water levels rose slowly in 1984 and, due to reduced Liard River floodwaters and the relatively high level of the Mackenzie River at the time of freezeup in 1983 (resulting in thicker ice), breakup was delayed again until May 22 (C. Sikstrom, pers. comm.).

To summarize, water levels do influence staging snow goose use of the Mackenzie River by altering the availability of habitat. Extensive flooding of habitat occurred in the Norman Wells area in 1981 as a result of an ice jam at Rader Island. Rising water levels associated with breakup of the Liard River often cause flooding of early-successional habitat. Although observations made during the years studied seem to suggest that departure of snow geese from a certain site appears to conform to the timing of breakup, this is probably coincidental. Other work has shown that departure of snow geese frequently precedes breakup (T. Barry, pers. comm.).

5.13 Spring Season Chronology and Conditions on Southern Staging Areas

In this section, the effects of spring season chronology (factor 12) and habitat conditions at southern staging areas (factor 13) are discussed. Bellrose (1976) notes that as many as 350 000 snow geese (or about three-quarters of the entire Pacific Flyway population) congregate at Freezeout Lake, Montana in the spring (Figure 11). Flocks of several thousand geese stage in southeastern Alberta and west-central Saskatchewan (especially the Kindersley area) where they feed in grain fields before resuming their journey to nesting grounds on the Arctic coast.

Table 7 illustrates the chronology of migrating snow geese in the springs of 1980, 1981, 1983 and 1984. Detailed compilations of snow goose observations made during spring migration are found in Appendices XVII to XX. In 1981 and 1983, snow geese left Freezeout

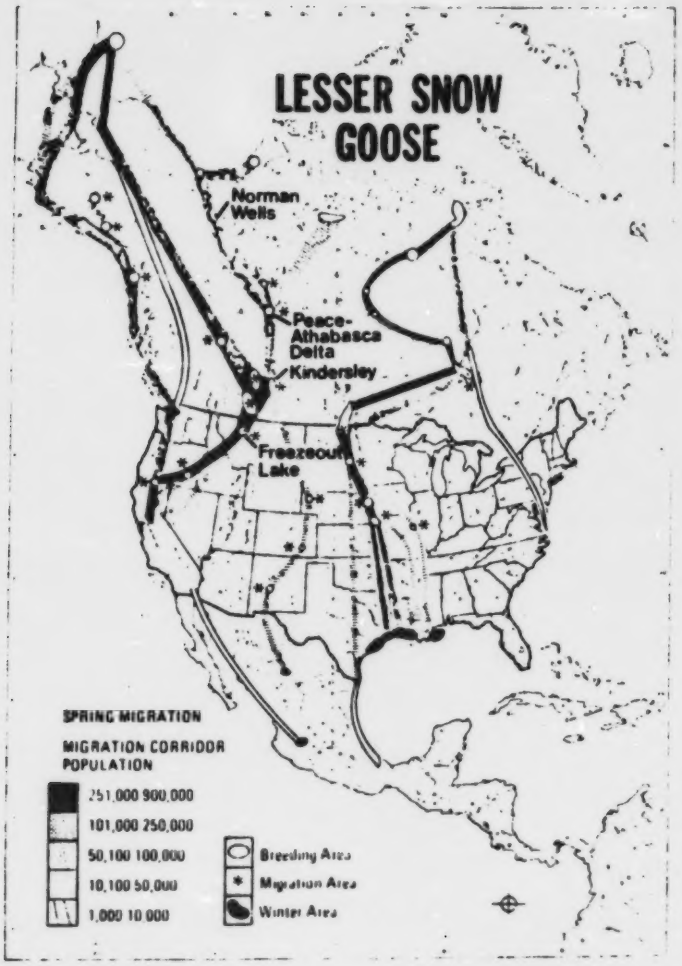

Figure 11. Migration corridors used by snow geese in the spring.

Source: adapted from Bellrose (1976)

Table 7. Snow goose spring migration chronology in 1980, 1981, 1983 and 1984.

Stage of migration	DATE			
	1980	1981	1983	1984
Large-scale departure from Freezeout L., Montana a/	April 8	March 22	March 26	?
First observation at Peace-Athabasca Delta or points north a/	April 25	April 10	April 19	April 2
Last observation in Alberta or Saskatchewan a/	May 9	May 14	May 7	?
First observation at Norman Wells area b/	May 2	April 24	May 4	April 2 (Brackett L.)
Peak numbers at Norman Wells c/	May 9	May 12	May 18	May 10
Last observation at Norman Wells c/	May 15	?	May 29	?

a/ Environmental Management Associates (1980, 1982, 1983, 1984)

b/ 1980 - R. Webb Environmental Services Ltd. (1980)
1981, 1983 - Environmental Management Associates (1982, 1983)
1984 - Environmental Management Associates (1984)

c/ 1980, 1981 - R. Webb Environmental Services Ltd. (1980, 1983)
1983 - D. Ealey (pers. comm.)
1984 - author

Lake in large numbers about a week apart (March 22 and 23 in 1981, March 16 in 1983). However, in 1980, movements of large flocks out of the area occurred about two weeks later than in 1981 on April 7 and 8. A relatively mild winter, with below-normal snowfall coupled with above-normal evaporation losses, resulted in drought conditions in the spring of 1980 in southern Alberta and Saskatchewan. An overflight of prairie ducks into boreal forest habitat in northern parts of the prairie provinces that year was evidence of the poor water conditions present (Brazda 1980). Snow goose flocks of a thousand or more were not recorded in the prairies except in the Kerrobert-Kindersley area of west-central Saskatchewan (Figure 11, Appendix XVII).

Extreme drought conditions prevailed in 1981; sheetwater and semi-permanent wetlands were non-existent (Benning 1981). However, snow goose staging was more widely distributed than in 1980 (Appendix XVIII). Possibly due to dry prairie conditions, or perhaps due to the earlier departure from Freezeout Lake, snow geese arrived in northern Alberta and Saskatchewan about two weeks earlier in 1981 than in 1980 (Table 7).

The spring of 1983 saw dry conditions persisting in the western part of Saskatchewan (Benning 1983). As in 1981, snow goose flocks observed were small in size and distributed throughout southeastern Alberta and west-central Saskatchewan (Appendix XIX). While a small number of geese (less than 100) were seen at Fort Simpson, N.W.T. as early as

April 19, numerous geese were still observed in west-central Saskatchewan as late as May 7.

Drought conditions persisted in southwestern and south-central Saskatchewan in 1984 and spring was generally two to three weeks early (Benning 1984). Very few observations of snow geese were made and large flocks were not seen (Appendix XX). The geese appeared to have spent very little time at southern staging areas, heading north as soon as conditions would allow. This is evidenced by their presence at Brackett Lake, north of Fort Norman (see Figure 1), as early as April 2 (R. Bullion, pers. comm.) and at Paulatuk on the arctic coastline on May 3 (P. Latour, pers. comm.).

Examination of the limited data available does not reveal any obvious relationship between spring habitat conditions at southern staging areas and snow goose migration chronology. This may be because the goose observation data used was mostly collected on an incidental, opportunistic basis rather than through systematic surveys. However, it is also possible that the degree and timing of staging goose use of prairie and parkland habitat is influenced more by other variables, such as weather, which override the effects of local habitat conditions. The influence of weather variables (factors 9, 10 and 14) on snow goose movements is discussed in the following section. It should be noted that spring season chronology (factor 12) is essentially a result of prevailing weather systems which are characterized by various weather variables.

5.14 Weather Conditions

It was stated in the previous section that, due to a combination of climatic factors, prairie habitat became free of snow early in the season in 1980, 1981, 1983 and 1984 and above-normal temperatures acted to aggravate the very dry conditons. Mean temperatures experienced in Saskatchewan and Alberta during those years are shown in Tables 8 to 11. Mean temperatures in both April and May exceeded the long-term monthly mean at all meteorological stations listed (including two arctic locations) and in all years studied.

Although some researchers found intensity of migration (i.e. extent of migratory movements) of some birds to be related to temperature, Blokpoel and Gauthier (1975) did not find any such correlation for snow geese. Temperature (factor 10) appears to influence snow goose migration indirectly through effecting habitat changes, such as removal of ice from ponds or snow from fields, or by encouraging evaporation of wetlands. However, Blokpoel and Gauthier (1975) did find that the intensity of snow goose migration was greater when precipitation (factor 9) was less than normal.

Wind direction (factor 14) was found to be a significant factor influencing snow goose migration in studies conducted in the Winnipeg, Manitoba area by Blokpoel and Gauthier (1975). Richardson and Gunn (1971) found the same relationship to exist for migrating birds in general at Cold Lake, Alberta. Blokpoel (1973) considered winds out

Table 8. Mean temperature (°C) in April and May, 1980 compared to long-term monthly means (1951-80).

Meteorological station	April		May	
	Mean for 1980 a/	Long-term mean b/	Mean for 1980 a/	Long-term mean b/
Kindersley, Sask.	9.6	-2.6	14.2	3.6
Provost, Alta.	9.0	-2.9 c/	13.8	3.5 c/
Meadow Lake, Sask.	8.0	-2.5	11.9	3.8
Fort Chipewyan, Alta.	6.6	-7.4	9.7	1.5
Fort Simpson, N.W.T.	4.1	-8.8	10.4	1.4
Norman Wells, N.W.T.	-6.8	-13.4	7.0	-0.4

a/ Atmospheric Environment Service (1980a,b)

b/ Atmospheric Environment Service (1982)

c/ Coronation station (data unavailable for Provost)

Table 9. Mean temperature (°C) in April and May, 1981 compared to long-term monthly means (1951-80).

Meteorological station	April		May	
	Mean for 1981 a/	Long-term mean b/	Mean for 1981 a/	Long-term mean b/
Kindersley, Sask.	5.8	-2.6	12.6	3.6
Provost, Alta.	5.6	-2.9 c/	12.8	3.5 c/
Meadow Lake, Sask.	3.6	2.5	11.1	3.8
Fort Chipewyan, Alta.	-3.9	-7.4	9.8	1.5
Fort Simpson, N.W.T.	-4.5	-8.8	11.7	1.4
Norman Wells, N.W.T.	-5.7	-13.4	10.9	-0.4

a/ Atmospheric Environment Service (1981a,b)

b/ Atmospheric Environment Service (1982)

c/ Coronation station (data unavailable for Provost)

Table 10. Mean temperature (°C) in April and May, 1983 compared to long-term monthly means (1951-80).

Meteorological station	April		May	
	Mean for 1983 a/	Long-term mean b/	Mean for 1983 a/	Long-term mean b/
Kindersley, Sask.	4.5	-2.6	10.2	3.6
Provost, Alta.	3.6	-2.5	9.1	4.6
Meadow Lake, Sask.	3.4	-2.5	8.0	3.8
Fort Chipewyan, Alta.	-0.5	-7.4	3.7	1.5
Fort Simpson, N.W.T.	-1.6	-8.8	4.6	1.4
Norman Wells, N.W.T.	-5.7	-13.4	1.6	-0.4

a/ Atmospheric Environment Service (1983)

b/ Atmospheric Environment Service (1982)

Table 11. Mean temperature (°C) in April and May, 1984 compared to long-term monthly means (1951-80).

Meteorological station	April		May	
	Mean for 1984 a/	Long-term mean b/	Mean for 1984 a/	Long-term mean b/
Kindersley, Sask.	7.6	-2.6	10.6	3.6
Hanna, Alta.	7.2	-2.9 c/	9.1	3.5 c/
Meadow Lake, Sask.	8.1	-2.5	8.0	3.8
Fort Chipewayan, Alta.	3.5	-7.4	7.8	1.5
Fort Simpson, N.W.T.	2.7	-8.8	9.1	1.4
Norman Wells, N.W.T.	-2.6	-13.4	8.5	-0.4

a/ Atmospheric Environment Service (pers. comm.)

b/ Atmospheric Environment Service (1982)

c/ Coronation station

of the S-E quadrat and zero precipitation to be favourable for spring bird migration at Cold Lake.

Blokpoel's guidelines were used to evaluate the effects of precipitation and wind direction on spring snow goose migration in the present study. A detailed analysis of 1980, 1981, 1983 and 1984 data is contained in Appendix XXI. The following are the conclusions of that analysis.

Data on snow goose movement in relation to precipitation was sparse. Therefore, no conclusions could be formed on the influence of precipitation on migrating snow geese. There was one observation made in 1980 of a flock of snow geese flying upstream (opposite from the normal direction of spring movement) during snowfall. All other observations of snow goose movements were made on days when there was no precipitation. However, this does not necessarily mean that these flights would not have occurred if there had been precipitation on those days.

Although no statistical analysis was performed on the data, a correlation between snow goose movements and wind direction was evident. More often than not, snow goose flights occurred when winds originated from the S-E quadrat or when calm conditions prevailed. On examination of the figures contained in Appendix XXI, it is also apparent that periods of favourable winds were more extended at Fort Simpson, and particularly at Norman Wells, than at other locations

in the migration corridor.

Wind data for 1980, 1981 and 1983, collected at five meteorological stations was divided into favourable and unfavourable categories (Table 12). A higher percentage of winds were favourable at Fort Simpson and Norman Wells than at the Alberta and Saskatchewan stations. At both of the northern locations, the Mackenzie River is oriented in a roughly NW-SE direction, coinciding with the path of snow goose migration in the spring. At Norman Wells, the river is situated between two mountain ranges: the Mackenzie Mountains and the Norman Range. The two ranges tend to funnel winds along a NW-SE axis (Eley 1974). Geographic characteristics of the Norman Wells reach of the Mackenzie River, then, are condusive to the occurrence of winds coincident with the direction of spring snow goose flights. This factor would tend to encourage the use of the reach by snow geese.

As noted in Appendix XXI, there was very little correlation between the timing of snow goose movements and wind direction in the Norman Wells area in 1984. In addition, use of the Mackenzie River by snow geese was sparse; on one day, there were more geese observed at Brackett Lake than on the Mackenzie River between the Keele River and Tieda River inflows.

It is known that, in some years, when migration has been delayed by adverse weather conditions on the prairies, for example, snow geese will sometimes select an alternate route which bypasses a portion or

Table 12. Wind direction at locations along the snow goose migration corridor - 1980, 1981 and 1983.

Meteorological station	Wind direction	
	% favourable [a]	% unfavourable [b]
Kindersley, Sask.	48.6 [c]	50.7
Meadow Lake, Sask.	40.2	59.3
Fort Chipewyan, Alta.	44.5	55.6
Fort Simpson, N.W.T.	56.7	42.1
Norman Wells, N.W.T.	56.8	41.7

a/ E, ESE, SE, SSE, S and calm

b/ N, NNE, NE, ENE, SSW, SW, WSW, W, WNW, NW, and NNW

c/ mean calculated from April and May, 1980, 1981, and 1983 data

Source: Atmospheric Environment Service (pers. comm.)

all of the Mackenzie River and allows them to reach the nesting grounds faster (T. Barry, pers. comm.). In these instances, Brackett Lake may serve as an important final staging area before the geese fly non-stop to arctic coastal areas. Alternatively, the geese may fly directly from northern Alberta to the arctic coast. In 1984, there were very few observations of snow goose flocks made in Alberta and Saskatchewan. It appears that the extremely dry conditions, warm temperatures and early spring stimulated the birds to proceed north early. Snow geese were observed at Brackett Lake as early as April 2 (R. Bullion, pers. comm.). In the Mackenzie valley region, the geese would have experienced relatively warm temperatures and habitat which was undergoing thaw earlier than usual. At the time of the aerial surveys, many more of the ponds located off-river and on river islands were already partially or totally ice-free in 1984 than in 1983. This must have given many geese a further stimulus to head directly for the breeding grounds rather than following the more leisurely route along the Mackenzie River. This would explain their arrival at the arctic coast about two weeks earlier than normal and the low numbers of geese observed on the Mackenzie River during the 1984 aerial surveys.

5.2 Influence of the Norman Wells Project on Snow Geese

Not including construction work at Esso's facilities on the mainland, the oilfield expansion project can be considered to comprise three phases: production island construction, well drilling and oilfield production (Table 13). The 1983 waterfowl studies were conducted during the production island construction phase. Drilling had been occurring on Bear Island but had halted before the studies

Table 13. Simplified schedule of the Norman Wells Oilfield Expansion Project.

Project phase	1983	1984	1985	1986+
Island construction	...———			
Well drilling[a/]	——[b/]	———	———	
Oilfield production			———	...

Source: D. Fennell (pers. comm.)

a/ Bear, Frenchy, Goose and production islands

b/ drilling on Bear Island shut down during breakup (April 15 - June 20)

began. Construction was still continuing at four of the islands at the time of the 1984 studies and well drilling had begun on Rayuka and Rampart (Figure 2).

Oil production from the expanded production facilities began on March 6, 1985 (C. Sikstrom, pers. comm.). Well-drilling at the production islands is expected to be completed by the fall of 1985. Two additional new drilling pads are planned for Goose Island with construction beginning in the summer of 1985. Drilling on the pads is scheduled for completion by early February 1986. Further drilling on Frenchy and Bear islands during February, March and April of 1986 will mark the end of drilling activity associated with the Norman Wells oilfield.

The level and type of activities which took place in 1983 and 1984, during the island construction and well-drilling phases, were different from what would normally occur during the oilfield production phase. Therefore, the possible effects of the project on snow goose use of the Norman Wells area are considered in two parts: (a) during the island construction and well-drilling (or oilfield preparation) period and (b) during the oilfield production phase.

5.21 Oilfield Preparation Period

Since construction of the production islands began, Esso has funded two field studies during which project-related and non-project-related disturbances of snow geese were monitored. McCourt Management Ltd.

conducted the first study in May of 1983 (Ealey and Scott-Brown 1984) and R. Webb Environmental Services Ltd. (1984) conducted the second study in May 1984. The main results of these studies are reported here in assessing the influence of the project on snow geese during the island construction and well-drilling phases.

5.211 Observations in 1983

Drilling activity on Bear Island had already shut down prior to the start of the McCourt Management monitoring work and drilling had not yet begun on the production islands. However, frequent helicopter service flights were required between the mainland and a barge mooring basin at Bear Island. During the period the study was conducted (May 3-25), the number of flights each day ranged from 16 to 72, each flight representing one leg of a trip (e.g. Norman Wells to Goose Island or Goose Island to Bear Island). This is considerably more than the average of 8 to 20 daily flights required to complete drilling of a new well (C. Sikstrom, pers. comm.). Therefore, the situation in 1983 was one which potentially could have resulted in greater disturbance of staging waterfowl than activities normally associated with drilling of a well.

Ealey and Scott-Brown (1984) recorded a total of 127 human-related disturbances of waterfowl. Only one was due to ground activity; a noise caused by starting of machinery at the barge mooring site caused a small group of geese resting on the ice to fly up. They returned to the same location 500 m from the barge site and resumed resting.

Ealey and Scott-Brown (1984) noted that 74 (59 percent) of the remaining 126 waterfowl disturbances due to aircraft were associated with Esso's activities in the Norman Wells area. Of these, 61 were due to helicopter flights to Bear Island and 13 resulted from river ice surveys flown by Esso's Twin Otter. The remaining aircraft disturbances were caused by commercial jets (16 percent), single-engine aircraft used on waterfowl surveys (12 percent), other fixed-wing aircraft (12 percent) and helicopters used by McCourt Management biologists during their study (2 percent). It should be noted that these data include incidental observations as well as observations made during scheduled observation periods. Table 14 does not include the incidental observations.

The responses of each waterfowl species to disturbances were not reported separately. However, it was noted that snow geese were the most sensitive of all waterfowl to aircraft flights. In a mixed waterfowl group, they were invariably the first to fly when an aircraft approached. Ealey and Scott-Brown (1984) classified responses into three categories: "alert", "flight" and "migrate". An "alert" response occurred when there was an increase in the percentage of waterfowl that became alert (i.e. neck straight, head raised and usually oriented in the direction of the disturbance). A "flight" response usually consisted of birds rising up and then returning to the same general location. Occasionally, the birds would circle for a longer period of time before landing. A "migrate" response was exhibited

Table 14. Types and duration of waterfowl responses to disturbances caused by aircraft in May 1983.

Aircraft type	Response[a/]			Duration of response (min.)			
	Alert	Flight	Migrate	<1	1 - 3	>3	unknown
Non-project-related aircraft (fixed-wing, jet, helicopter)	1	24	1	1	21	1	3
Project-related aircraft (helicopter)	2	26	3	7	15	3	6
Study-related aircraft (fixed-wing, helicopter)	-	21	-	5	15	1	-
Total	3 (4)[b/]	71 (91)	4 (5)	13 (17)	51 (65)	5 (6)	9 (12)

a/ see text for definition of response types

b/ percentage

Source: adapted from Ealey and Scott-Brown (1984)

when birds flew away from the disturbance to a new location downstream (out of view). This response, of course, was the most severe and disruptive to the staging birds in terms of energy loss.

Table 14 shows that 91 percent of the aircraft disturbances resulted in a flight response. For both types of disturbance, the duration of response was most frequently (65 percent) between one and three minutes. Ealey and Scott-Brown (1984) determined that, in 1983, aircraft disturbed waterfowl feeding and resting activities about 39 minutes per day.

Considering all observed responses to aircraft, the percentage of flights which caused disturbance of waterfowl was greatest for those at altitudes between 150 and 500 m above ground level (agl) (Table 15). All but one of the 132 helicopter flights to and from Bear Island were at low altitude (less than 150 m agl). Only 11 (8 percent) of the 131 low-altitude helicopter flights caused any disturbance of waterfowl (Ealey and Scott-Brown 1984). Waterfowl also responded to the one flight which occurred at 150-500 m agl.

Almost all of the aircraft flights followed routes which were located more than 0.5 km from staging bird flocks. Considering all aircraft types, 70 percent of the flights which occurred between 0.5 and 1.0 km from staging waterfowl produced a noticeable response (Table 16). At distances of between 1.0 and 5.0 km, only 11 percent of the flights caused a response. With only one exception, waterfowl did not respond

Table 15. Responses of waterfowl to aircraft flights at different altitudes in May 1983.

Flight altitude (m agl)	Number of flights		
	Response	No response	Total
<150	16 (12)[a/]	120 (88)	136
150 - 500	16 (67)	8 (33)	24
>500	14 (13)	97 (87)	111

a/ percentage

Source: Ealey and Scott-Brown (1984)

Table 16. Responses of waterfowl to aircraft flights at different distances in May 1983.

Aircraft type	Distance from aircraft to staging birds (km)		
	0.5 - 1	>1 - 5	>5
Jet			
Response	3[a/] (50)[b/]	7 (35)	1 (9)
No response	3 (50)	13 (65)	10 (91)
Fixed-wing (except jet)			
Response	7 (88)	10 (14)	-
No response	1 (12)	61 (86)	15 (100)
Helicopter			
Response	10 (67)	6 (5)	-
No response	5 (33)	112 (95)	3 (100)
Total			
Response	20 (70)	23 (11)	1 (3)
No response	9 (30)	186 (89)	28 (97)

a/ number of flights that caused a response

b/ percentage

Source: Ealey and Scott-Brown (1984)

to flights which occurred more than 5.0 km away.

5.212 Observations in 1984

At the time of the R. Webb Environmental Services Ltd. study, four of the production islands had been constructed: Rayuka, Rampart, Dehcho and Ekwe (Figure 2). Drilling rigs operated 24 hours per day on Rayuka and Rampart but there were no manned facilities present on Dehcho or Ekwe. The two remaining islands (Iteh K'ee and Little Bear) were not completed until fall of 1984. In addition to well drilling on Rayuka and Rampart, Esso was also involved in lease cleanup activities on Goose and Bear islands, barge preparation at the mooring facilities at Bear Island and survey work on Dehcho and Ekwe (R. Webb Environmental Services Ltd. 1984).

Scheduled helicopter flights took place four times daily from the mainland to Bear, Rayuka and Rampart islands. On some days, particularly close to breakup, there were additional flights. Daily flights were made to Goose, Dehcho and Ekwe islands. Drilling operations on Rayuka and Rampart ceased on May 12 in preparation for breakup. However, daily flights to the islands were still made after May 12 to enable general rig maintenance to be carried out.

Between May 4 and 16, R. Webb Environmental Services Ltd. (1984) recorded 17 man-related disturbances which elicited 30 responses from groups of snow geese and dark geese staging on or adjacent to Bear, Goose or Frenchy islands. Project-related helicopter flights were responsible for 13 (43 percent) of the responses. The remaining

responses were due to commercial jets (13 percent), single-engine aircraft used on waterfowl surveys (30 percent), a truck on Goose Island (7 percent) and a truck (backfiring) on Dehcho Island (7 percent).

R. Webb Environmental Services Ltd. (1984) did not classify the responses to disturbance in the same manner as Ealey and Scott-Brown (1984) did in their 1983 study ("alert", "flight" and "migrate"). All responses recorded in 1984 consisted of visible flights of goose flocks. Table 17 shows responses exhibited by snow geese only. Twenty snow goose flocks displayed one of three reactive flight responses: "fly and return", "fly and relocate", and "migrate". The "fly and return" response is comparable to Ealey and Scott-Brown's "flight" response: geese flew up and returned to the same location. When the geese relocated to a different staging site in the Goose/Bear Island complex, a "fly and relocate" response occurred. Geese exhibited a "migrate" response when they left the area for an unknown destination.

The largest portion (65 percent) of the snow goose flocks returned to the same staging area following the disturbance (Table 17). Twenty percent moved to a new staging area while only a few flocks actually vacated the area altogether. Eighty percent of the flight responses lasted three minutes or less. Only one of the helicopter disturbances caused a response which exceeded three minutes.

R. Webb Environmental Services Ltd. (1984) observed that geese resting on or near Frenchy, Goose or Bear Islands never took flight when

Table 17. Types and duration of responses of snow geese to man-related disturbances in May 1984.

Disturbance type	Response [a]			Duration of response (min.)			
	Fly and return	Fly and relocate	Migrate	<1	1 - 3	>3	unknown
Helicopters [b]	6	1	1	4	2	1	1
Commercial jets [c]	3	-	-	1	2	-	-
Single-engined aircraft [c]	4	-	1	3	1	-	1
Trucks	-	3	1	2	1	-	1
Total	13 (65) [d]	4 (20)	3 (15)	10 (50)	6 (30)	1 (5)	3 (15)

[a] see text for definition of response types

[b] Esso project-related

[c] non-project-related

[d] percentage

Source: R. Webb Environmental Services Ltd. (1984)

helicopters serviced the drilling operations on Rayuka and Rampart. Most of the project-related disturbances of geese appeared to occur when helicopters overflew staging areas on or adjacent to Goose Island. No waterfowl were observed to take flight as a result of noise or activity related to drilling operations on Rampart or Rayuka. In addition, overflights of migrating geese appeared to not be diverted away from the river by either the drilling activities or simply the presence of the production islands.

5.213 Other Disturbance Studies

A number of researchers have investigated disturbance effects of human activities on snow geese. However, some of these studies were conducted at times other than during spring migration (i.e. during breeding, moulting and fall staging). Salter and Davis (1974) and Davis and Wiseley (1974) both studied responses to aircraft exhibited by snow geese feeding and resting on the Yukon North Slope in September prior to fall migration. Two other studies dealt with the reactions of fall staging geese to noise from gas compressor simulators (Gollop and Davis 1974, Wiseley 1974). Barry and Spencer (1976) documented the influence of drilling operations and aircraft flights on birds at the Taglu oil well site in the Mackenzie River delta. Included in the study were breeding, non-breeding and moulting snow geese, white-fronted geese, Canada geese and tundra swans. Because snow geese may react differently to a given disturbance type during spring, summer and fall, the results of the above studies are not reported here.

Some snow goose disturbance observations were made during spring staging at Norman Wells in 1980 and 1981 by R. Webb Environmental Services Ltd. (1980 and 1983, respectively). As in 1983 and 1984, snow geese most commonly responded to aircraft disturbance by taking flight and returning to the same location (Tables 18 and 19). In both 1980 and 1981, flight responses most often lasted three minutes or less. In 1980, most of the responses resulted from aircraft flights at altitudes greater than 150 m agl (Table 20). In comparison, most of the responses in 1983 were caused by aircraft flying at altitudes in the 150-500 m range (Table 15). Almost all of the aircraft flights monitored in 1980 occurred at distances of between 1 and 5 km from snow goose flocks. Half of the flights caused the geese to flush (Table 21). In comparison, only 11 percent of the flights in 1983, which were within the same distance range, resulted in a flight response.

Environmental Management Associates have monitored the effects of oil-pumping activities on migrating waterfowl at the Hay-Zama lakes complex in northwestern Alberta since 1980. During their spring 1980 study, Environmental Management Associates (1980) observed that, when approached by helicopter at an altitude of 91 m, geese would flush at distances of 1.6 km and remain in flight for up to 2.5 minutes. At an altitude of 305 m, the geese would not flush unless the helicopter passed within 0.8 km of the birds.

Table 18. Types and duration of responses of snow geese to aircraft flights in May 1980.

Aircraft type	Response[a/]			Duration of response (min.)			
	Fly and return	Fly and relocate	Migrate	<1	1 - 3	>3	unknown
Helicopters	2	-	-	1	1	-	-
Large fixed-wing[b/]	5	-	2	2	3	-	2
Small fixed-wing[c/]	7	-	3	1	6	-	3
Total	14 (74)[d/]	-	5 (26)	4 (21)	10 (53)	-	5 (26)

a/ see text for definition of response types

b/ Twin Otter, 737 jet, Electra

c/ small single-engined and twin-engined aircraft

d/ percentage

Source: R. Webb Environmental Services Ltd. (1980)

Table 19. Types and duration of responses of snow geese to aircraft flights in May 1981.

Aircraft type	Response[a/]			Duration of response (min.)			
	Fly and return	Fly and relocate	Migrate	<1	1 - 3	>3	unknown
Helicopters	2	1	1	1	2	-	1
Large fixed-wing[b/]	5	-	1	3	-	1	2
Total	7 (70)[c/]	1 (10)	2 (20)	4 (40)	2 (20)	1 (10)	3 (30)

a/ see text for definition of response types

b/ Twin Otter, 737 jet, Lear jet

c/ percentage

Source: R. Webb Environmental Services Ltd. (1983)

Table 20. Responses of snow geese to aircraft flights at different altitudes in May 1980.

Flight altitude (m agl)	Number of flights		
	Response	No response	Total
<150	1 (20) a/	4 (80)	5
150 - 500	16 (76)	5 (24)	21
>500	5 (83)	1 (17)	6

a/ percentage

Source: R. Webb Environmental Services Ltd. (1980)

5.214 Future Activities

At the time this report was being written, Esso had received approval from COGLA, following consultation with CWS, to reduce the standby period for drilling on Little Bear (the production island closest to Bear Island) (Figure 12). As many as six helicopter trips to the island per day (i.e. 12 flights) would be required to support the drilling operation (D. Fennell, pers. comm.). This level of helicopter activity is comparable to that which occurred in 1984 and therefore would be less than what was experienced in 1983.

In order to assess the potential for disturbance of snow geese resulting from activities associated with drilling on Little Bear, the proximity of snow goose staging areas must be considered. Two areas are located within one kilometre of Little Bear: one on the northern shore of Bear Island, the other between Bear and Frenchy islands (Figure 12). Examination of snow goose use data shows that the northern shore of Bear Island receives very little use. More extensive use has occurred, on occasion, between Bear and Frenchy Islands. However, use is less intensive and less consistent than along Goose Island shorelines.

On the basis of the expected level of human activities and snow goose staging patterns, the level of snow goose disturbance in 1985 would probably be light and possibly less than in 1984. Snow geese may avoid using the two staging areas closest to Little Bear. However, this would constitute only a minor impact and is not a great concern.

Table 21. Responses of snow geese to aircraft flights at different distances in May 1980.

Aircraft type	Distance from aircraft to staging birds (km)		
	0.5 - 1	>1 - 5	>5
Large fixed-wing[a/]			
Response	-	7[b/] (58)[c/]	3 (100)
No response	-	5 (42)	-
Small fixed-wing[d/]			
Response	-	7 (47)	-
No response	2 (100)	8 (53)	-
Helicopter			
Response	-	1 (33)	-
No response	-	2 (67)	-
Total			
Response	-	15 (50)	3 (100)
No response	2 (100)	15 (50)	-

a/ Twin Otter, 737 jet, Electra

b/ number of flights that caused a disturbance

c/ percentage

d/ small single-engine and twin-engine aircraft

Source: R. Webb Environmental Services Ltd. (1980)

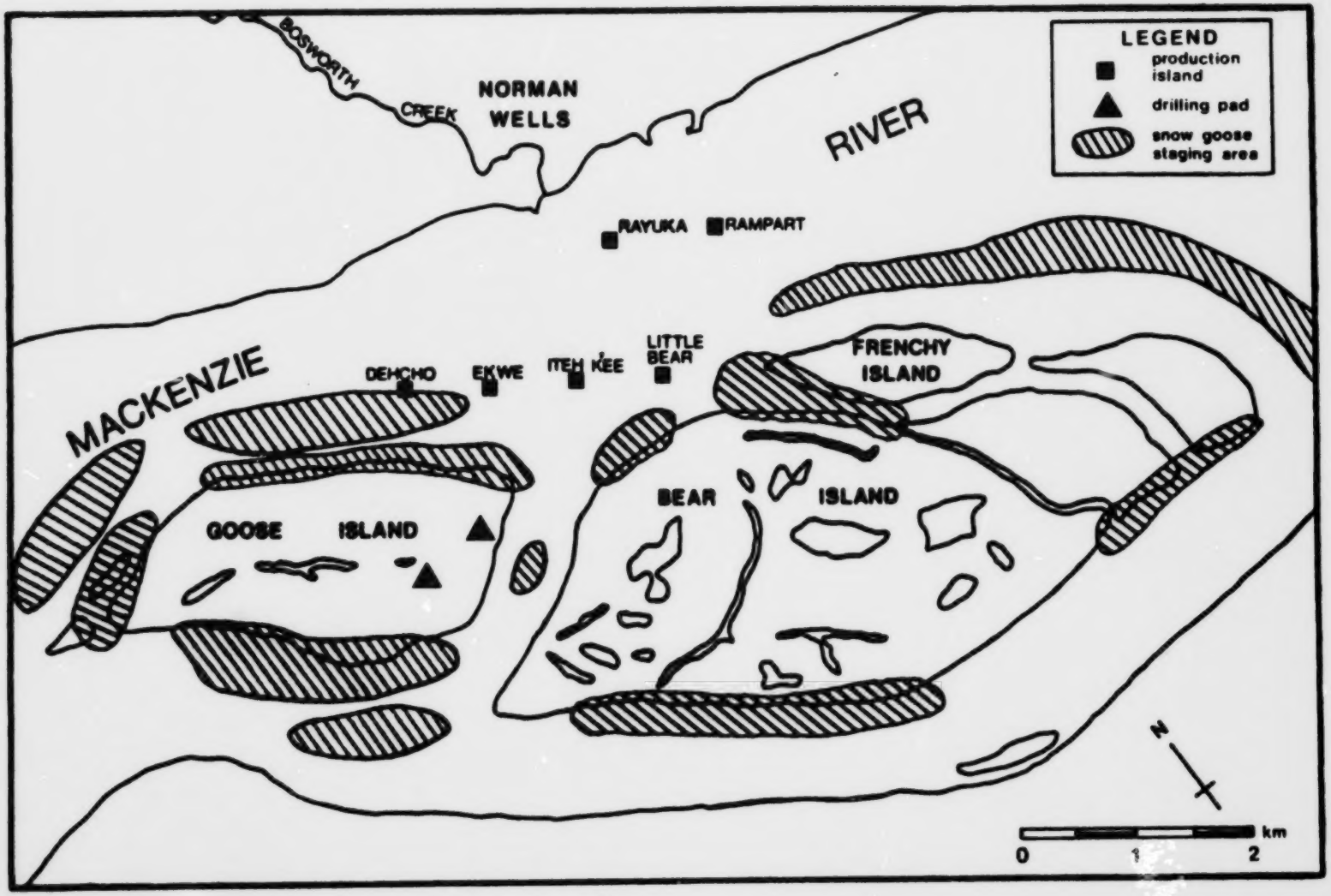

Figure 12. Locations of Esso's production islands, drilling pads and snow goose staging areas.

Sources: Campbell and Shepard (1973), R. Webb Environmental Services Ltd. (1980,1983,1984), Ealey and Scott-Brown (1984), author.

As was stated earlier in this report, two new drilling pads are to be built in the eastern part of Goose Island (Figure 12). The need for the new pad was indicated when recent drilling showed that the oil reservoir extended further south and west of the previously defined limits (D. Fennell, pers. comm.). Construction of the pads is to take place during the summer and fall of 1985, well after the waterfowl staging period. Therefore, there should be no impacts on waterfowl associated with pad construction activities. Some loss of habitat would occur at the pad sites and in the adjacent areas where sand is to be scraped from the island surface for construction of the pads. However, the amount of habitat lost would be small relative to the amount of habitat present along the southern shoreline of Goose Island. Provided that important habitat types such as Equisetum beds are avoided, impacts caused by habitat loss should be minor. Snow geese make extensive use of this habitat during the spring (Figure 12). Esso received advice from CWS concerning avoidance of these habitats because of the proximity of the pads to important staging areas. Drilling at the pads will occur during the winter of 1985-86 and should be completed well before the following spring migration period. Therefore, drilling activities on the new pads will not disturb staging waterfowl.

5.22 Oilfield Production Phase

Once all production wells have been drilled and connected by pipeline to Esso's mainland facilities, helicopter support activity will be much reduced. Wells on the production islands, and on Goose and Bear islands, will be controlled remotely from the mainland. However,

periodic on-site inspections would still be necessary involving one or two helicopter trips per day to one or more of the islands. This level of activity is expected to have only a minor influence on use of the Norman Wells area by snow geese and other waterfowl.

6. SUMMARY

Sections of the Mackenzie River between Ten Mile Island and Patricia Island (including the Norman Wells area) and between Fort Good Hope and Tieda River were the most heavily used by snow geese in 1983. Preferential use of these reaches was not as pronounced in 1984. The peak number of snow geese recorded in the study area in 1984 (9 755) was substantially less than the maximum number present in 1983 (44 641). A large number of snow geese (6 107) were observed in the Brackett Lake area, located about 40 km north of Fort Norman, on May 15, 1984.

The Norman Wells and Fort Good Hope - Tieda River areas were the most heavily used by dark geese in 1983. In 1984, the Beavertail Point - Hume Island reach, and to a lesser extent the Fort Good Hope - Tieda River area, received the most use. Ducks used every reach in the study area to some extent in both years while the reach downstream of Fort Good Hope was favoured by swans.

In 1972 and 1980, the Ten Mile Island - Mac Island reach was the most intensively used by snow geese. In 1981, snow geese used the river very little and use was almost totally limited to the Norman Wells area.

Considering snow goose use in all years studied, islands in the immediate Norman Wells area have received the most regular use. Sites on Patricia and neighbouring islands, the islands and mudflats downstream from Beavertail Point and some islands downstream of Fort

Good Hope have been important to varying degrees.

Habitat types preferred by staging snow geese - sparsely-vegetated mudflats and areas of Carex/Equisetum/willow growth - occur most abundantly in the Ten Mile Island - Mac Island reach (Norman Wells area) and between Beavertail Point and Hume Island. Desirable habitat also exists downstream of Fort Good Hope and, to a lesser degree, in the Ogilvie Island - Patricia Island reach.

The appearance of ice leads and bottomfast ice, and the pattern of spring breakup, varies from year to year depending on factors such as ice thickness and strength, air temperature and wind. However, the probability for extensive open water to be present is highest between Six Mile and Patricia islands and between Beavertail Point and Hume Island.

After considering the snow goose use data and distribution of favourable habitat and open water areas, four reaches were identified as being the most important to snow geese:

1) Ten Mile Island - Mac Island;
2) Ogilvie Island - Patricia Island;
3) Beavertail Point - Hume Island; and
4) a section of the Fort Good Hope - Tieda River reach.

Of these, the first reach in the vicinity of Norman Wells appears to be of highest importance. The Mackenzie River in general is important

for spring staging waterfowl since little suitable habitat, free of snow and ice, exists outside of the Mackenzie valley. Brackett Lake is the only significant area important for waterfowl between Great Slave Lake and the Mackenzie Delta.

The influence of a number of environmental factors on snow goose use of the study area was investigated. Snow geese appear to be attracted to areas of the Mackenzie River where preferred mudflat/sedge/willow habitat types are available and where there is a good probability of ice leads, flooded bottomfast ice and/or open water being present. An average of 81 percent of snow goose observations made in 1972, 1980, 1981, 1983 and 1984 were associated with mudflat/sedge/willow habitat types. Areas having open water and ice leads appear to receive moderate or substantial use by snow geese only when preferred habitat is also present. The formation of flooded bottomfast ice areas is directly related to the distribution of preferred habitat types; bottomfast ice and preferred habitat both tend to occur where low-gradient shorelines exist.

Increases in Mackenzie River water levels, originating largely from breakup of the Liard River, lead to the formation of cracks and leads in the ice and flooding of bottomfast ice. Water level rises also cause flooding, and therefore reduction, of preferred snow goose staging habitat. Departure of geese from a given reach of the river during the latter part of the migration period often appears to coincide with submergence of habitat resulting from rising water levels. Flooding of habitat can also result from the formation or

release of ice jams which are also associated with water level rises.

There does not appear to be a consistent correlation between habitat conditions in Alberta and Saskatchewan and the timing of snow goose migration in the Mackenzie River valley. In all four years studied (1980, 1981, 1983 and 1984), drought conditions prevailed in the prairie regions of Alberta and Saskatchewan. This tended to encourage snow goose flocks to overfly the prairies into boreal forest regions. However, unless spring is suitably well-advanced along the Mackenzie River, snow goose flocks will not continue their journey north. When spring is early in both the southern staging areas and the north, as in 1984, snow goose migration can proceed rapidly. In 1984, some snow geese arrived on the arctic coast as early as May 3. Use of the Mackenzie River was below normal that year; many snow geese apparently staged at Brackett Lake and flew directly overland to the coast rather than following the river. It is possible that the extensive open water and the large number of completely or partially ice-free ponds caused the snow geese to "conclude" that they were behind schedule. This being the case, the geese would have been stimulated to fly north using the most direct means rather than the more leisurely route down the Mackenzie River.

Analysis of the influence of weather variables on snow goose migration showed that snow goose movements often occurred during, or shortly after, periods of winds originating out of the S-E quadrat. This concurred with the findings of other researchers. However, there were also some instances where goose flights occurred during periods of

unfavourable winds. Favourable wind periods were more extensive and occurred more frequently at Fort Simpson and Norman Wells than at other locations in the south in 1980, 1981, and 1983. In the Norman Wells area, mountain ranges on each side of the Mackenzie River are oriented roughly NW-SE and act to funnel winds in directions favourable for snow goose migration. In addition, the Mackenzie River is also oriented in a NW-SE direction in the Norman Wells vicinity and this probably further augments the attractiveness of the Norman Wells area.

In order to monitor the influence of activities associated with the oilfield expansion project on spring waterfowl use of the Norman Wells area, Esso funded and coordinated field studies in May 1983 and 1984. Both studies were conducted during the oilfield preparation phase which included construction of production islands and drilling of production wells.

In 1983, all but one of the man-related disturbances of waterfowl observed were caused by aircraft flights. Fifty-nine percent of the reactive waterfowl flights were associated with Esso's project activities. Snow geese were the most sensitive of all waterfowl to aircraft flights. Considering all waterfowl species, 91 percent of all aircraft disturbances resulted in a "flight" response: the birds took flight, circled and returned to the same location. The most frequent duration of response was between one and three minutes; 65 percent of the responses lasted three minutes or less. It was estimated that, on average, project-related and non-project-related aircraft caused 39 minutes per day of disturbance in 1983. Aircraft flights at altitudes

of between 150 and 500 m above ground level (agl) produced the highest percentage of responses from waterfowl. Only eight percent of Esso's low altitude (less than 150 m agl) helicopter flights caused any disturbance of waterfowl.

In 1984, project-related helicopter flights were responsible for 43 percent of the observed man-related disturbances of waterfowl. The largest proportion (65 percent) of the disturbed snow goose flocks returned to the same staging area following the disturbance as in 1983. Eighty percent of the flight responses lasted three minutes or less. Geese resting on or near Frenchy, Goose or Bear islands never took flight when helicopters serviced the drilling operations on Rayuka and Rampart islands. Overflights of migrating geese did not appear to be diverted away from the Mackenzie River by either the presence of the production islands or the drilling activities occurring on them.

Observations on snow goose response to aircraft fights made previously in 1980 and 1981 appeared to concur with those made in 1983 and 1984. The most common response was for geese to flush and return to the same location within three minutes. Overall, comparing the data collected in 1980 and 1983, aircraft activities in 1983 appeared to be less disturbing than in 1980.

In 1985, drilling at Little Bear Island (one of the production islands) will extend into the spring migration period (C. Sikstrom, pers. comm.). Helicopter support flights will be required comparable

in number to that which occurred in 1984. Consideration of the level of disturbance of snow geese observed in 1983 and 1984, and the use of staging areas in the vicinity of Little Bear Island, indicates that disturbances of snow geese in 1985 can be expected to be light.

Construction of two additional drilling pads on Goose Island will necessitate a small reduction of habitat at the pad sites. However, provided that the pad locations avoid important goose staging habitat types, such as Equisetum beds, impacts would be minor. Waterfowl staging will not be affected by drilling activities on Goose Island because drilling is scheduled for the 1985-86 winter months.

Once all production wells have been drilled and connected up to Esso's facilities on the mainland, they will be operated remotely from the mainland. Helicopter flights will be reduced to daily or twice daily trips to the islands to check operation of the well facilities. This level of activity is not likely to have any significant influence on use of the Norman Wells area by snow geese and other waterfowl.

7. CONCLUSIONS

1. The Mackenzie River in general is important for spring staging waterfowl since, with the exception of Brackett Lake, little suitable habitat, free of snow and ice, exists outside the Mackenzie valley from Great Slave Lake to the Mackenzie Delta.

2. On the basis of historical use data and distribution of favourable habitat and open water areas, four reaches are considered to be the most important in the study area for spring staging snow geese:

(a) Ten Mile Island - Mac Island;

(b) Ogilvie Island - Patricia Island;

(c) Beavertail Point - Hume Island; and

(d) a section of the Fort Good Hope - Tieda River reach.

3. The Ten Mile Island - Mac Island reach, in the vicinity of Norman Wells, appears to be the most important of these reaches and the most regularly used by snow geese.

4. The attractiveness of the Norman Wells area is probably mostly due to the abundance of preferred habitat types: sparsely-vegetated mudflats and areas of Carex, Equisetum and willow growth. The NW-SE orientation of the river at Norman Wells, paralleling the direction of winds favourable for migratory movements, may also be a contributing factor.

5. Increases in Mackenzie River water levels influence habitat use by snow geese through flooding of low-elevation, preferred habitat. Departure of geese from a given reach during the latter part of the migration period sometimes coincides with submergence of habitat resulting from rising water levels.

6. In some years, when spring thaw conditions occur earlier than normal in the Mackenzie River valley, as in 1984, many snow geese may bypass the Norman Wells and downstream areas in favour of a more direct route to breeding areas on the arctic coast. The Brackett Lake area appears to serve as an important staging area, in those years, before the final flight to the coast.

7. Helicopter service flights were the chief sources of waterfowl disturbance associated with Esso's oilfield expansion project at Norman Wells in 1983 and 1984. For the most part, the response of waterfowl to aircraft disturbance was minor and short-term. When birds took flight, most often they returned to the same staging area within three minutes or less. This general trend was also observed in 1980 and 1981. Overall, aircraft flights in 1983 appeared to cause less disturbance to snow geese than in 1980. Neither the presence of the production islands nor drilling activity on the islands appeared to deter geese from using the Mackenzie River as a migration corridor in 1983 and 1984.

8. Construction and drilling activities associated with the two additional drilling pads on Goose Island will not be occurring during

the spring migration period and, therefore, will not disturb staging waterfowl. Some habitat will be lost at the pad sites. However, by avoiding important habitat types, such as Equisetum beds, as is planned, this impact should be minimal.

9. Once production wells are in place and operational on the islands, they will be operated remotely from the mainland and helicopter activity will be reduced to daily inspection trips. Flights to and from the production islands should not disturb snow geese to any great degree during the spring migration period.

8. RECOMMENDATIONS

1. CWS should conduct one more series of aerial waterfowl surveys on the Mackenzie River during the 1985 spring migration period. As in 1983 and 1984, the surveys should extend between the inflows of the Keele and Tieda rivers. Brackett Lake should be surveyed at the beginning and end of the Mackenzie River survey period.

2. Due to the proximity of the new drilling pads on Goose Island to important staging areas along the island's shoreline, helicopter flights, required to make inspection trips to the pads, should be kept to a minimum during the spring migration period. In order to minimize disturbance of waterfowl, all flights should approach the pads from the channel between Bear and Goose islands and departing flights should follow the same route. Flight altitudes should not exceed 150 m agl.

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10. APPENDICES

Appendix 1. Locations and numbers of snow geese in 1983.

Reach			May 2 [a]	May 5 [a]	May 8 [b]	May 10 [a]	May 12 [b]	May 13 [b]	May 17 [b]	May 18 [b]	May 23 [b]	May 24 [b]	May 29 [b]
Keele River km 740	-	Seagull Island km 800	- [c]	-	5 (1) [e]	28 (2)	. [d]	.	.	.	.	.	.
Police Island km 800	-	Windy Island km 840	-	-	135 (31)	400 (37)	.	.	.	.	.	.	.
Little Bear River km 840	-	Prohibition Creek km 880	-	-	7 (2)	-	.	.	.	.	.	.	.
Ten Mile Island km 880	-	Six Mile Island km 900	-	-	75 (17)	-	-	25 (1)	1 840 (23)	12 135 (40)	7 863 (18)	-	-
Bear Island km 900	-	Mac Island km 920	-	-	40 (9)	782 (62)	1 670 (82)	1 404 (60)	4 279 (52)	14 928 (50)	9 062 (20)	3 354 (11)	2 (18)
Rader Island km 920	-	Patricia Island km 960	-	-	90 (21)	45 (4)	352 (17)	907 (39)	1 100 (14)	715 (2)	5 361 (12)	6 507 (21)	-
Trapper Creek km 960	-	Carcajou Ridge km 1000	-	-	80 (19)	-	-	-	-	4 (<1)	6 (<1)	485 (2)	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	-	-	-	-	-	-	-	-	954 (2)	625 (2)	-
Dunvit Island km 1020	-	Hume Island km 1060	-	-	-	-	-	2 (<1)	-	-	2 210 (5)	2 152 (7)	9 (82)
Hume Island km 1060	-	Ramparts km 1100	-	-	-	-	10 (1)	-	-	16 (<1)	255 (1)	200 (1)	-
Fort Good Hope km 1100	-	Tieda River km 1160	-	-	-	-	-	-	853 (11)	2 315 (8)	18 930 (42)	18 214 (58)	-
TOTALS			-	-	432	1 255	2 032	2 338	8 072	30 113	44 641	31 537	11

[a] surveyed by CWS

[b] surveyed by McCourt Management Ltd. (pers. comm.)

[c] - = no snow geese observed

[d] . = not surveyed

[e] % of total observed that day

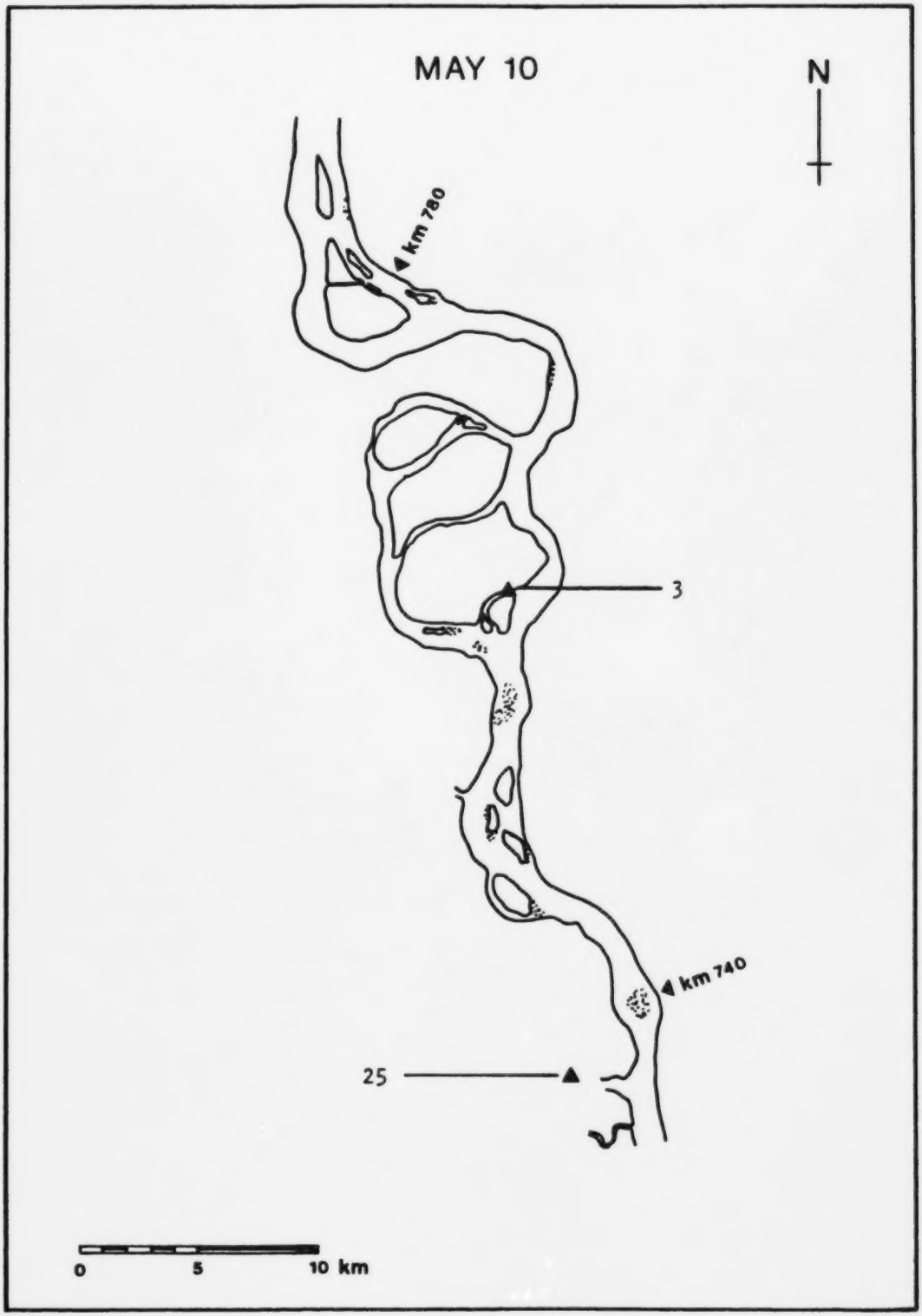
Appendix II: Locations and numbers of snow geese in 1984.[a/]

Reach			May 8	May 10	May 12	May 15
Keele River km 740	-	Seagull Island km 800	320 (3) [c/]	- [b/]	-	-
Police Island km 800	-	Windy Island km 840	32 (<1)	-	8 (<1)	-
Little Bear River km 840	-	Prohibition Creek km 880	8 (<1)	-	-	-
Ten Mile Island km 880	-	Six Mile Island km 900	67 (1)	-	3 (<1)	6 (<1)
Bear Island km 900	-	Mac Island km 920	2 225 (24)	1 098 (11)	730 (12)	510 (9)
Rader Island km 920	-	Patricia Island km 960	2 286 (25)	2 017 (20)	1 811 (29)	736 (13)
Trapper Creek km 960	-	Carcajou Ridge km 1000	12 (<1)	-	-	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	480 (5)	1 750 (18)	602 (10)	460 (8)
Dummit Island km 1020	-	Hume Island km 1060	2 352 (25)	3 850 (40)	1 250 (20)	1 270 (23)
Hume Island km 1060	-	Ramparts km 1100	440 (5)	270 (3)	150 (2)	655 (12)
Fort Good Hope km 1100	-	Tieda River km 1160	1 100 (12)	770 (8)	1 700 (27)	1 955 (35)
TOTALS			9 322	9 755	6 254	5 592

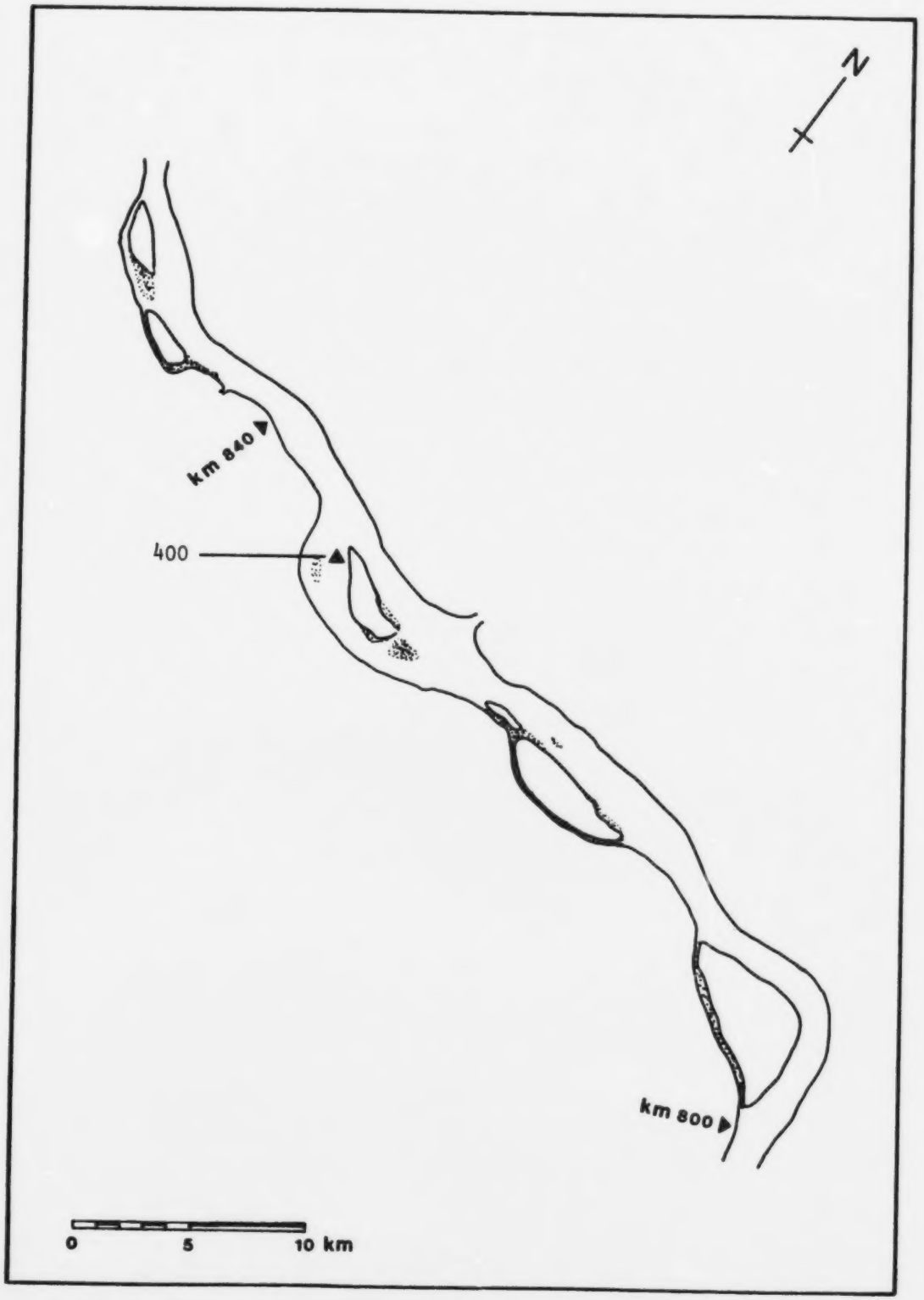
[a/] surveyed by CWS

[b/] - = no snow geese observed

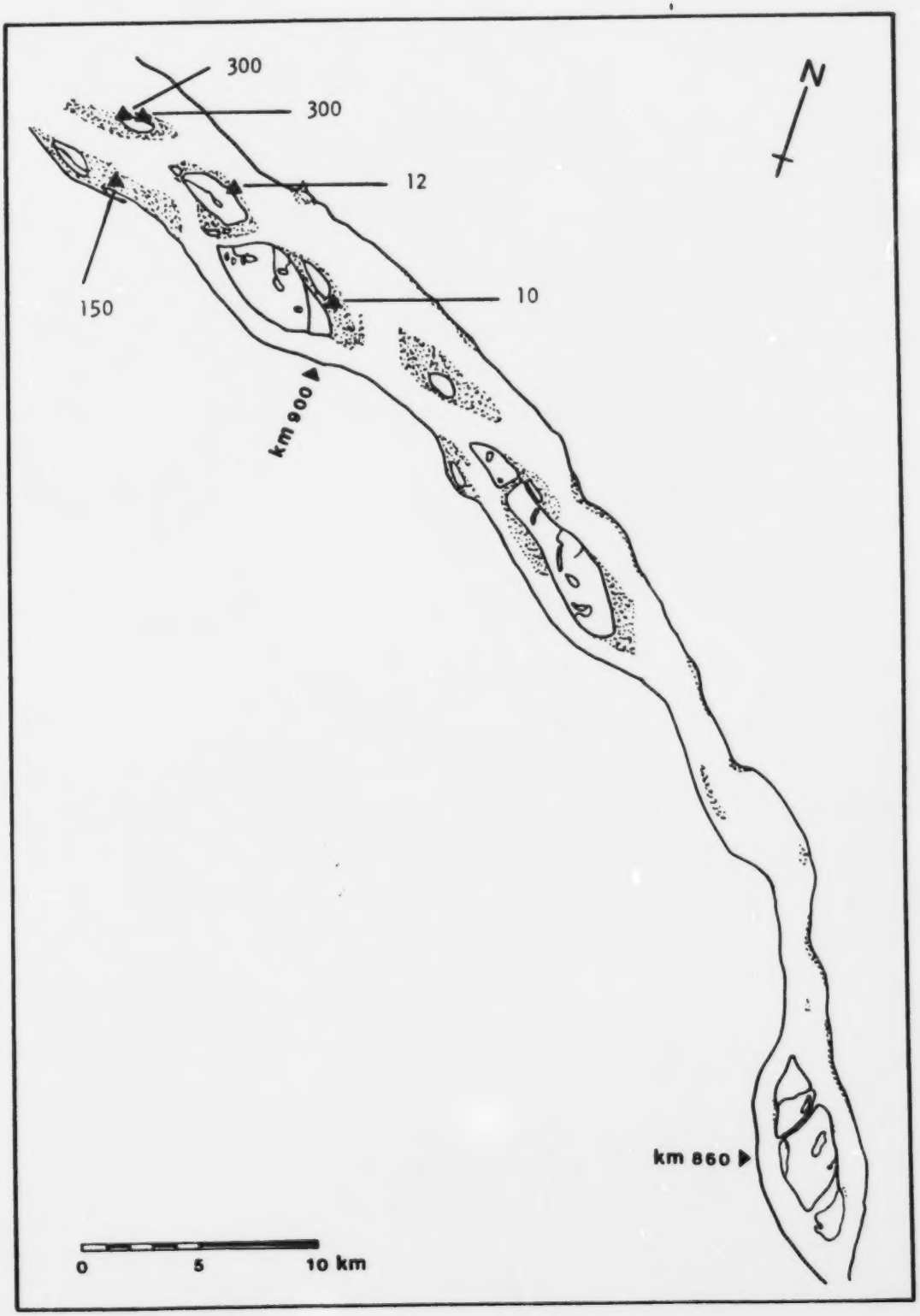
[c/] % of total observed that day



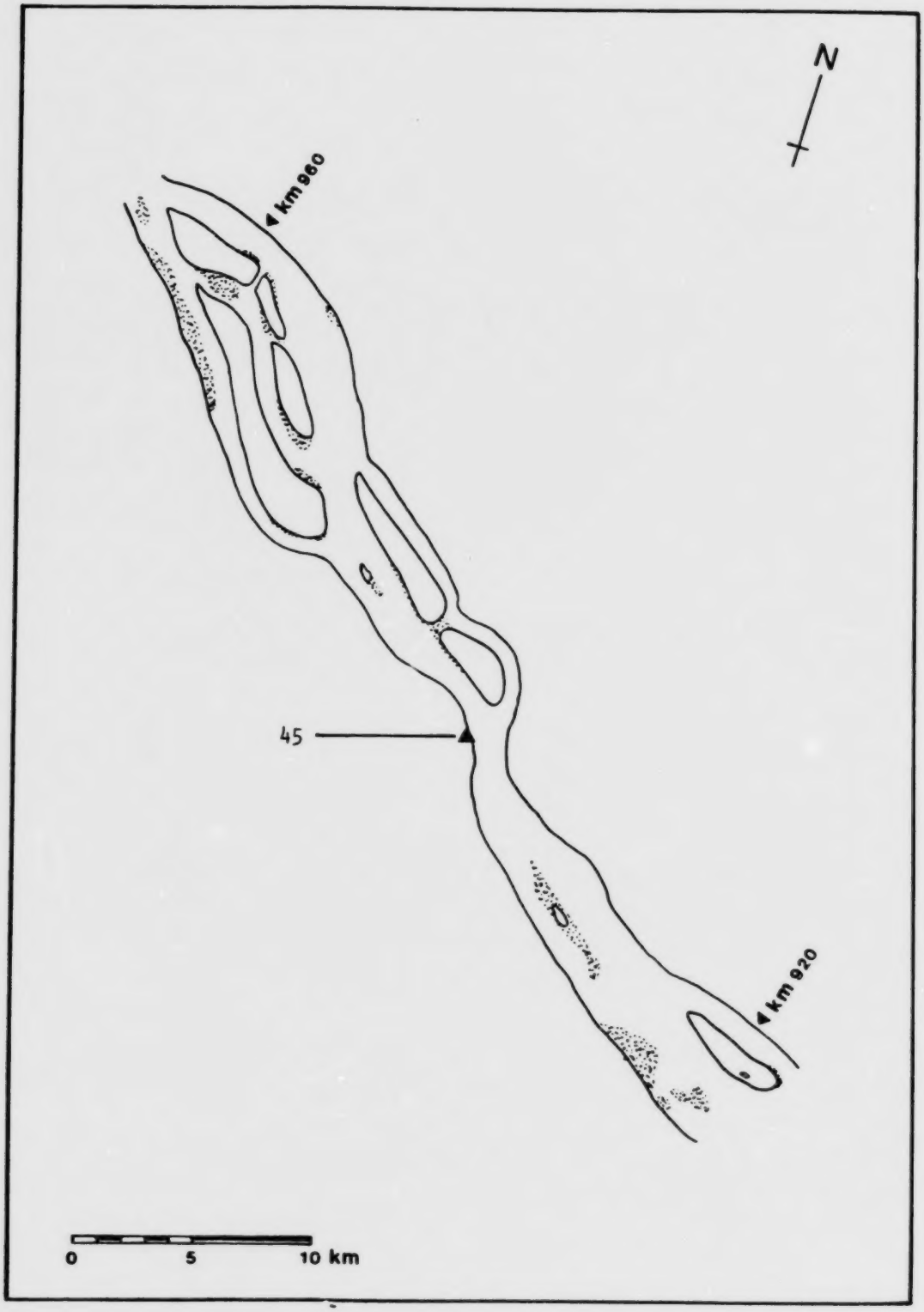
Appendix III. Locations of snow goose sightings in 1983.
(a) May 10



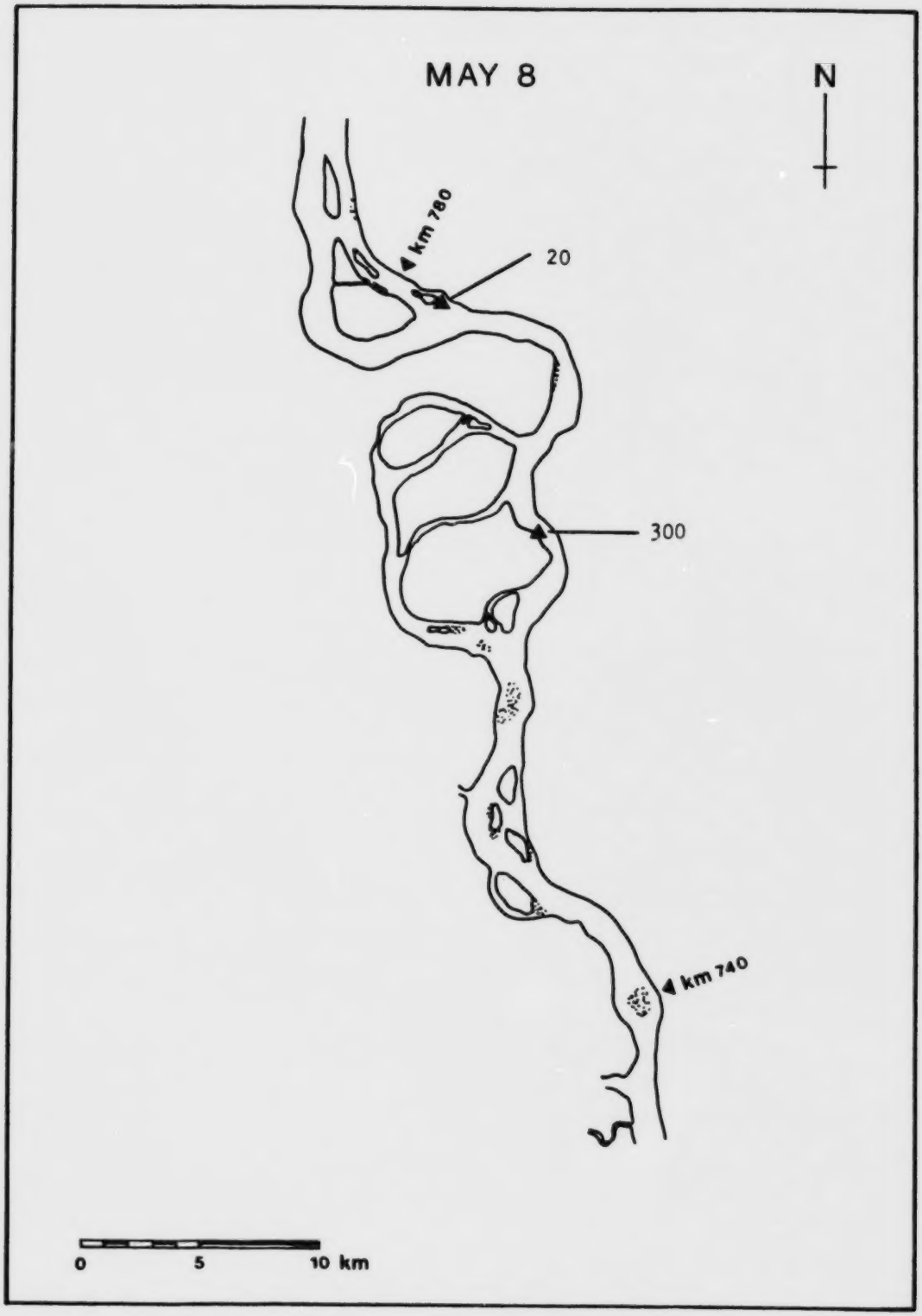
Appendix III(a)(cont'd)



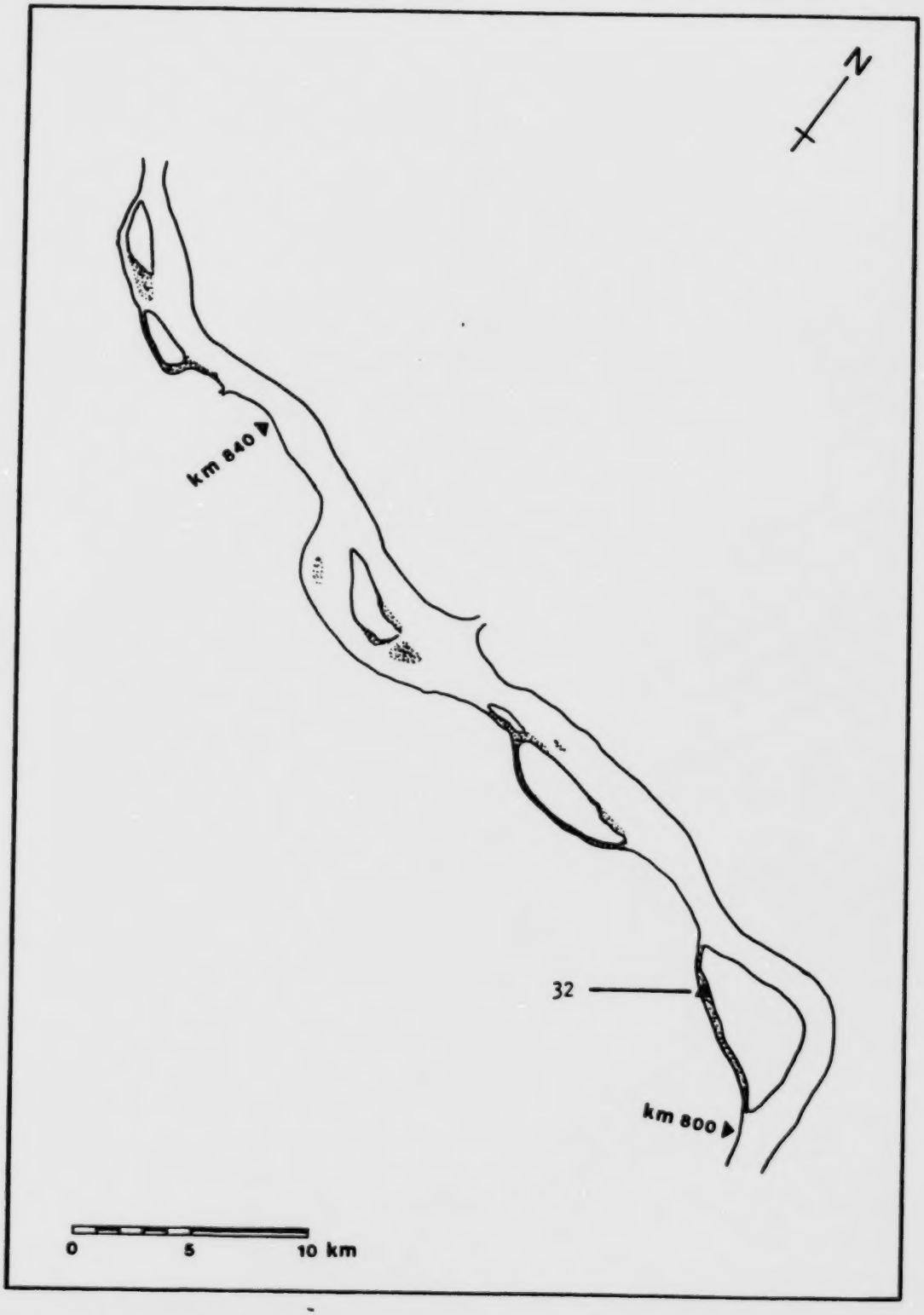
Appendix III(a)(cont'd)



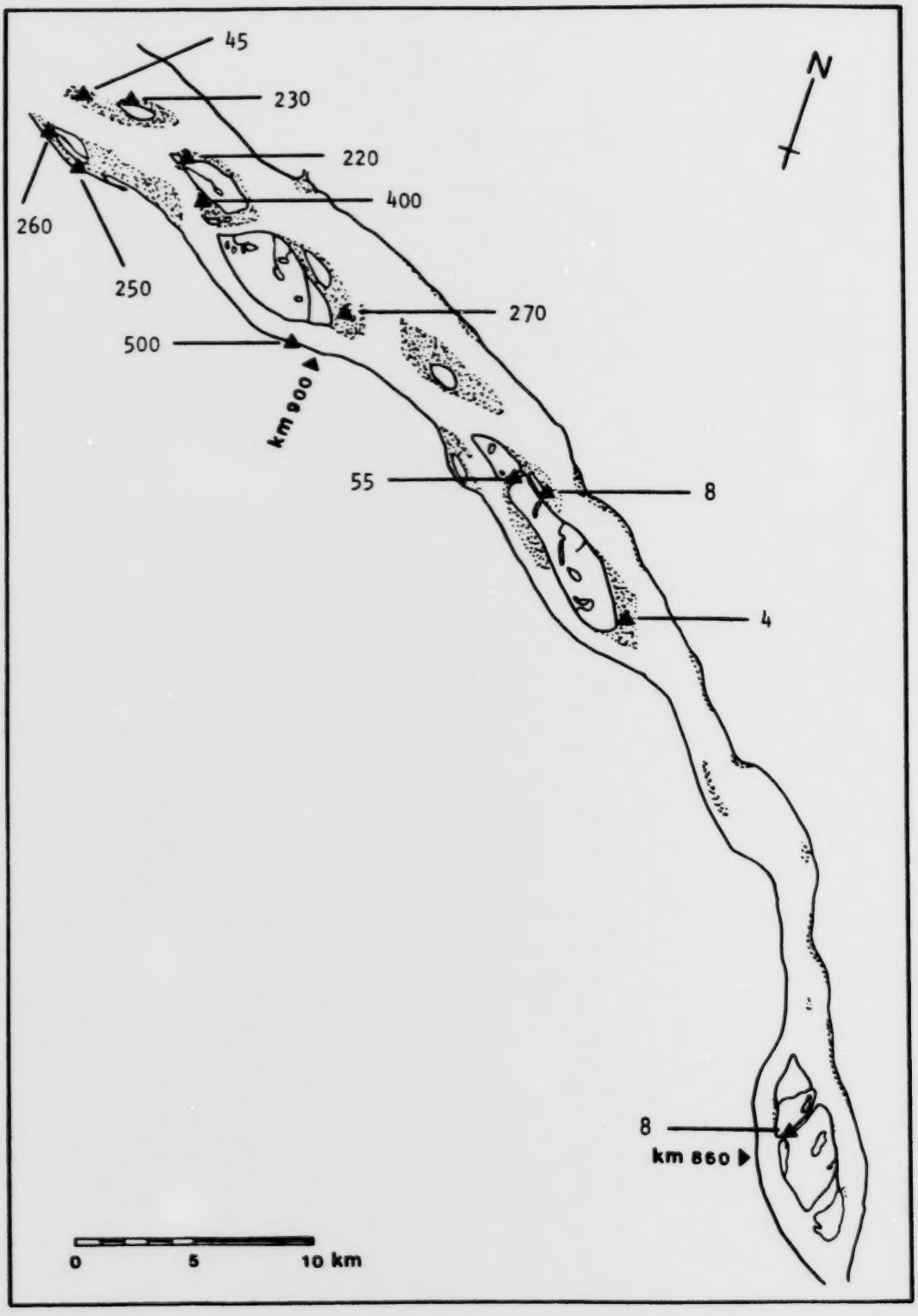
Appendix III(a)(cont'd)



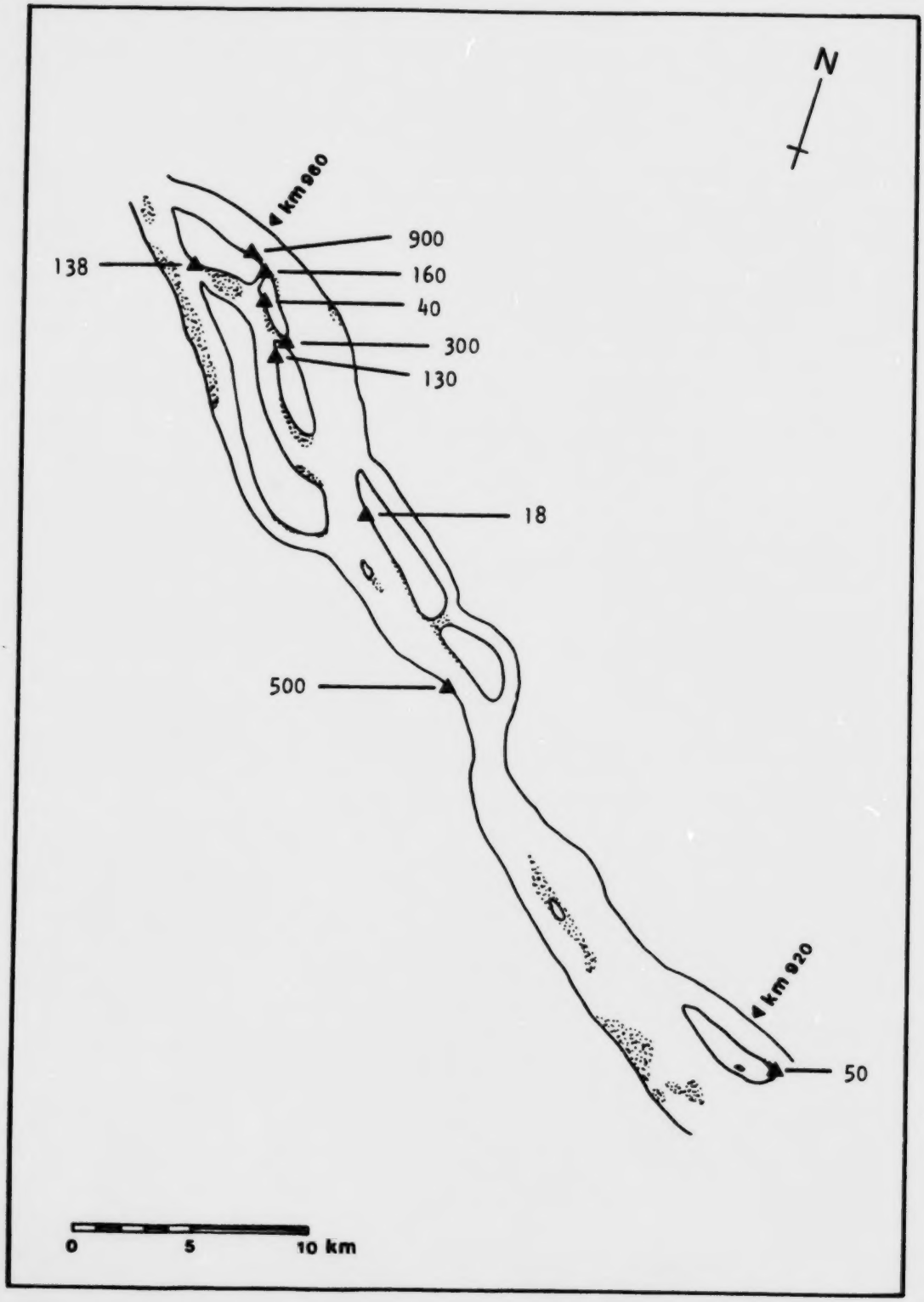
Appendix IV. Locations of snow goose sightings in 1984.
(a) May 8



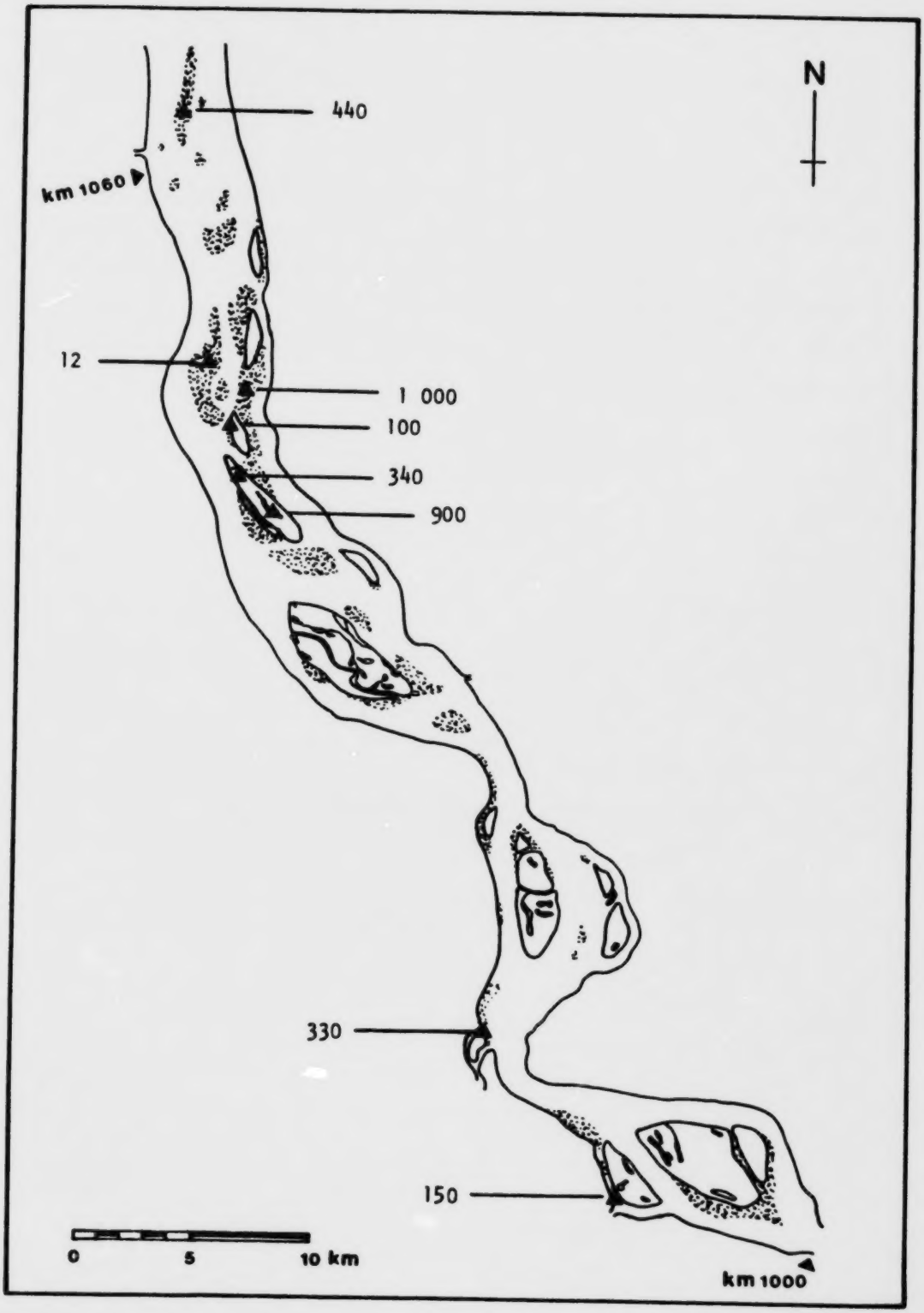
Appendix IV(a)(cont'd)



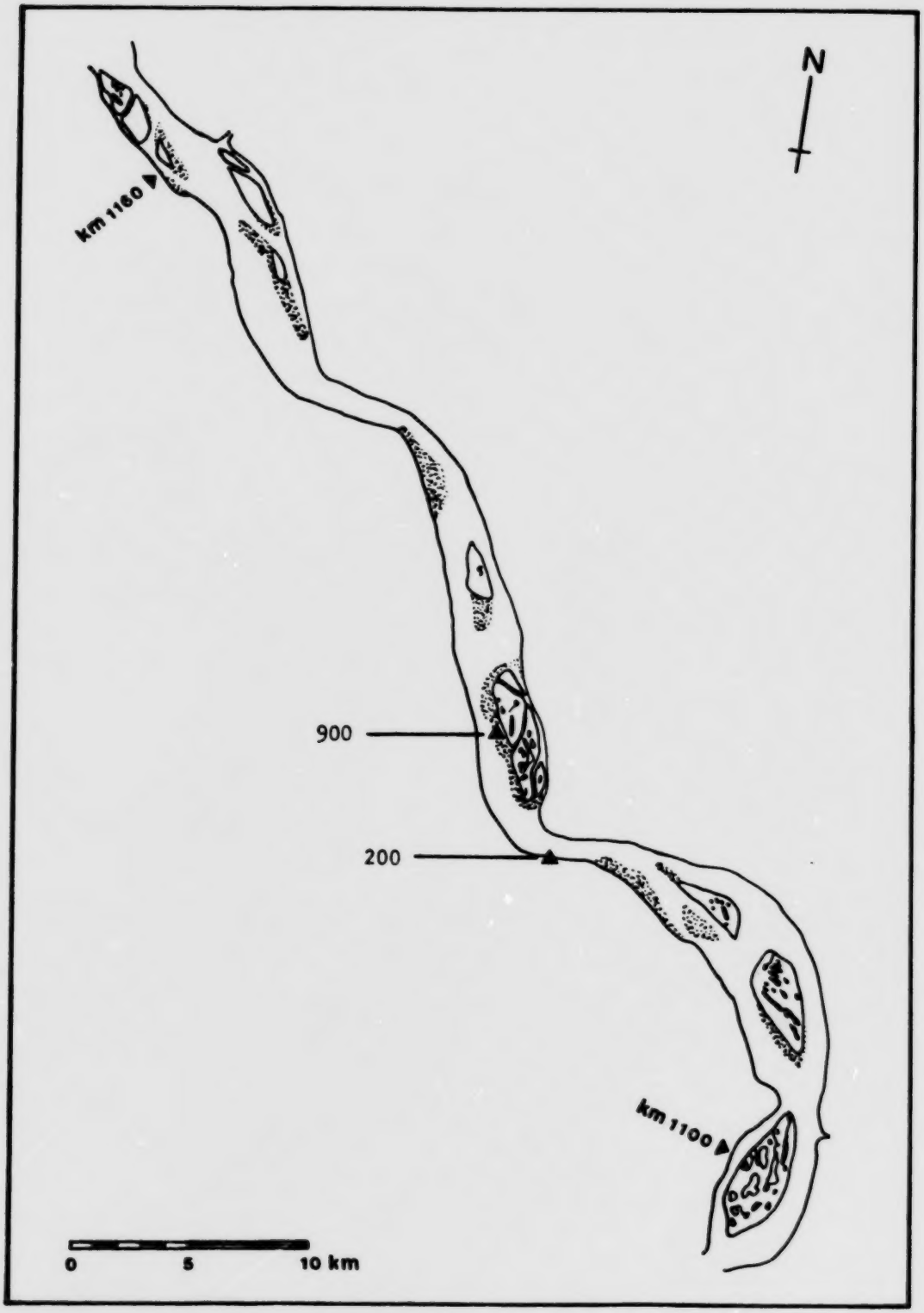
Appendix IV(a) (cont'd)



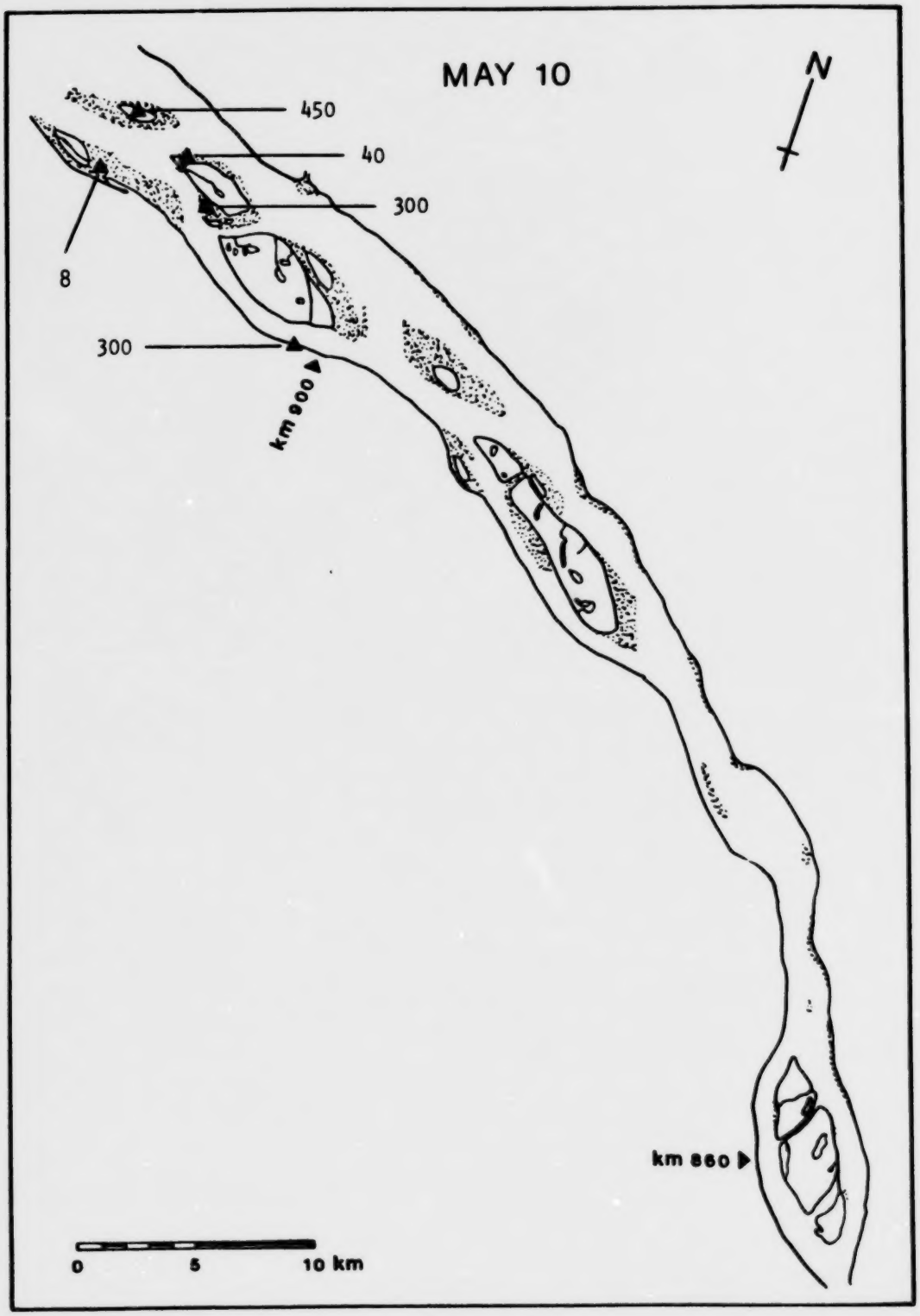
Appendix IV(a)(cont'd)



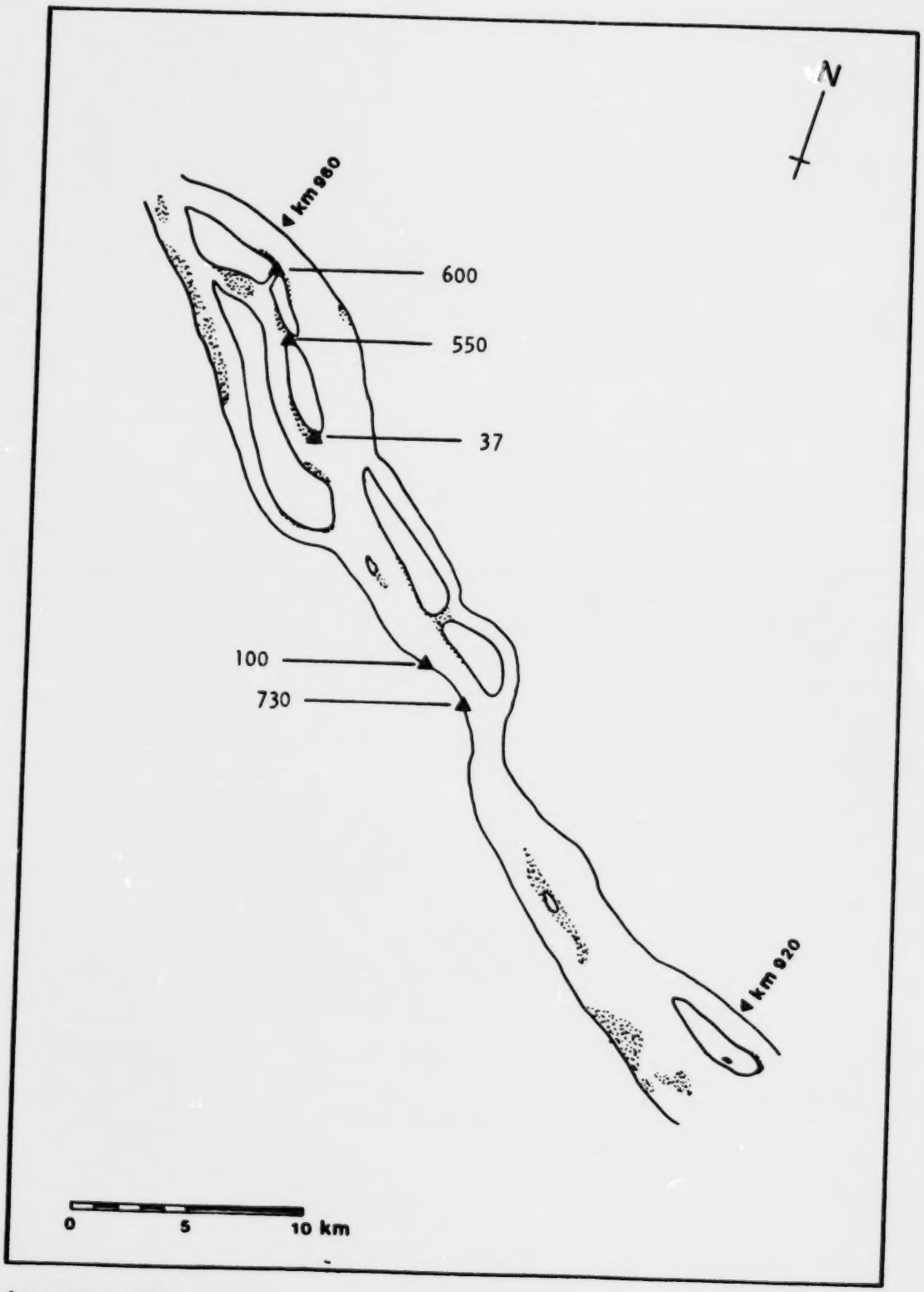
Appendix IV (a) (cont'd)



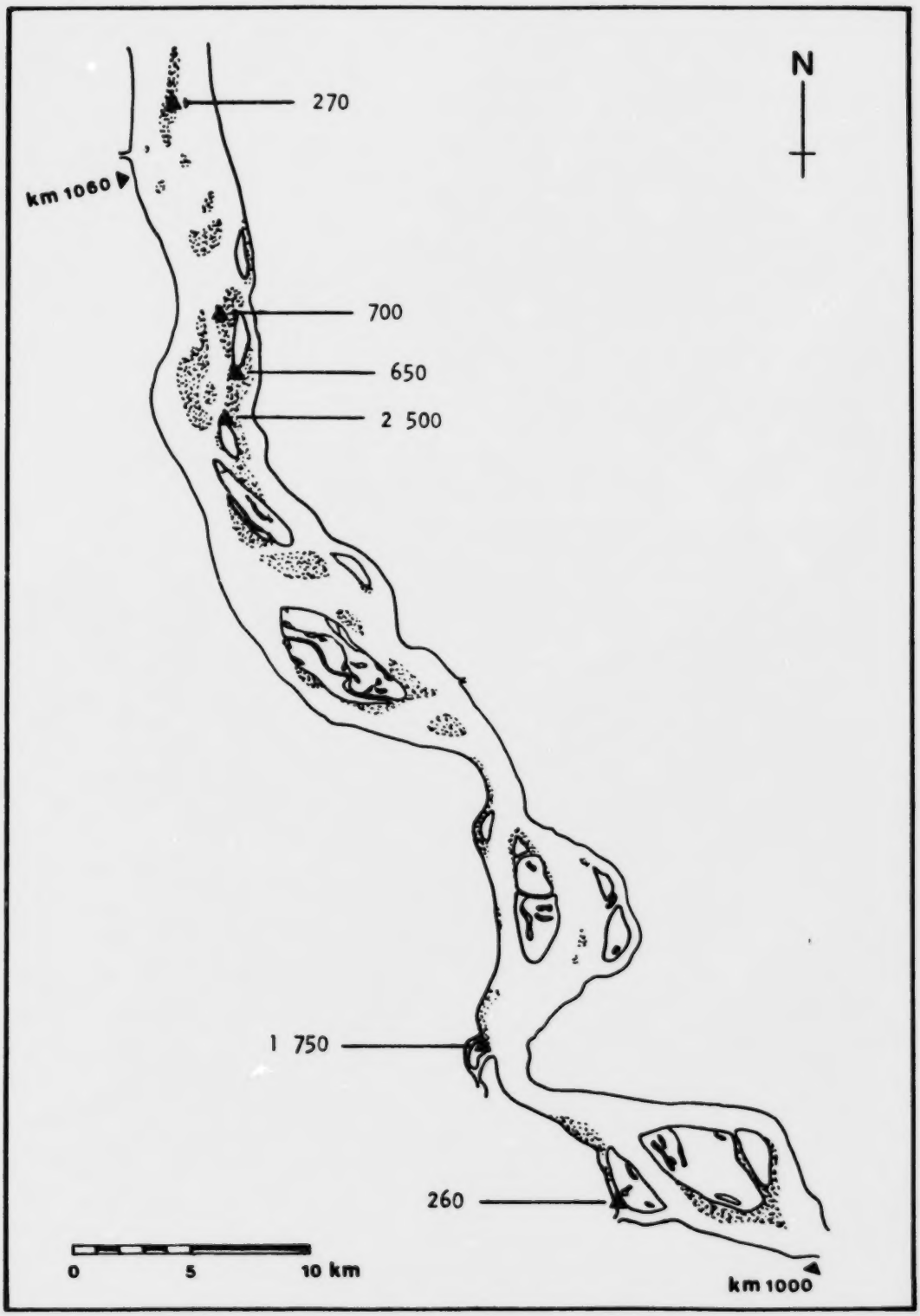
Appendix IV(a)(cont'd)



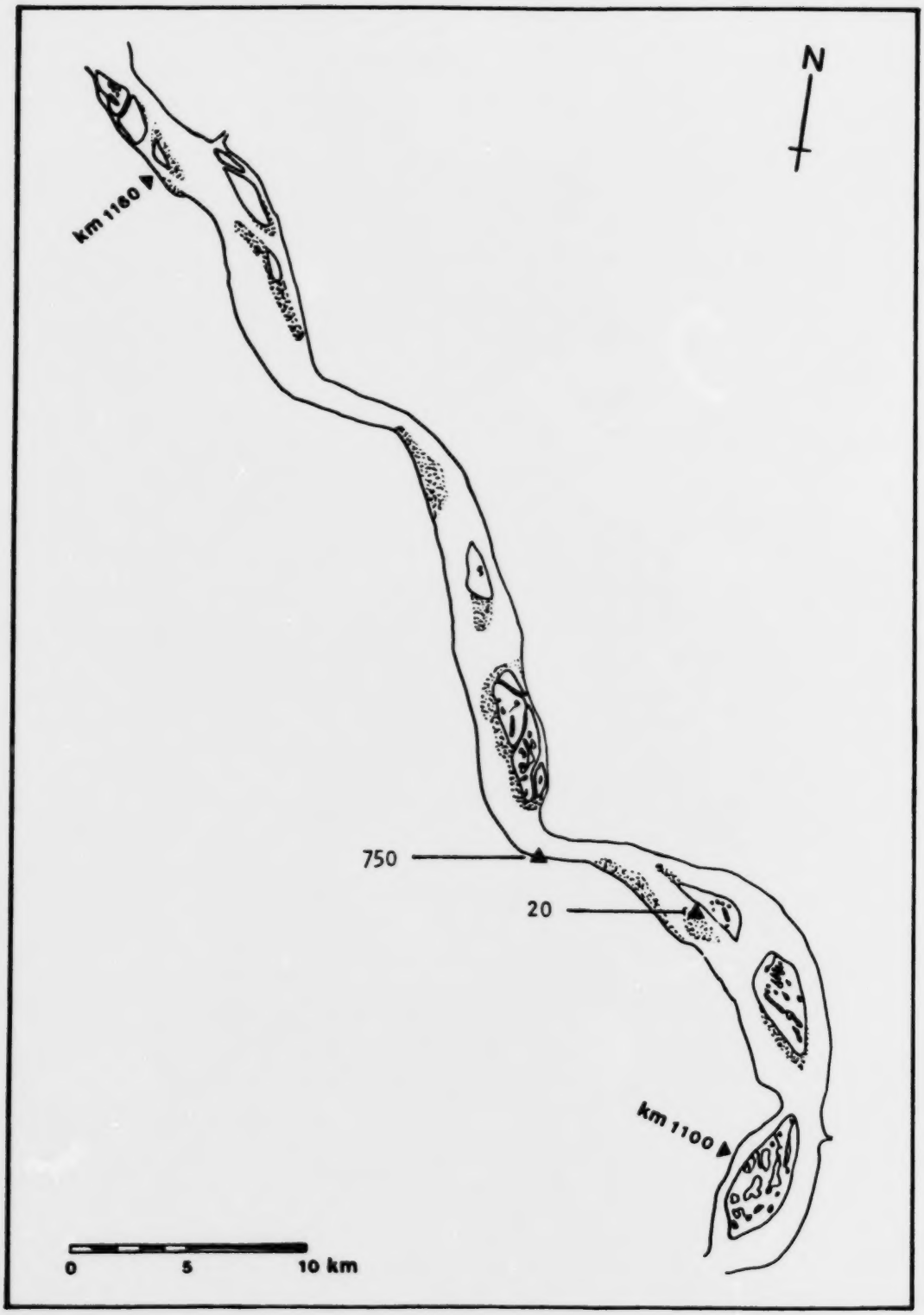
Appendix IV (b) May 10



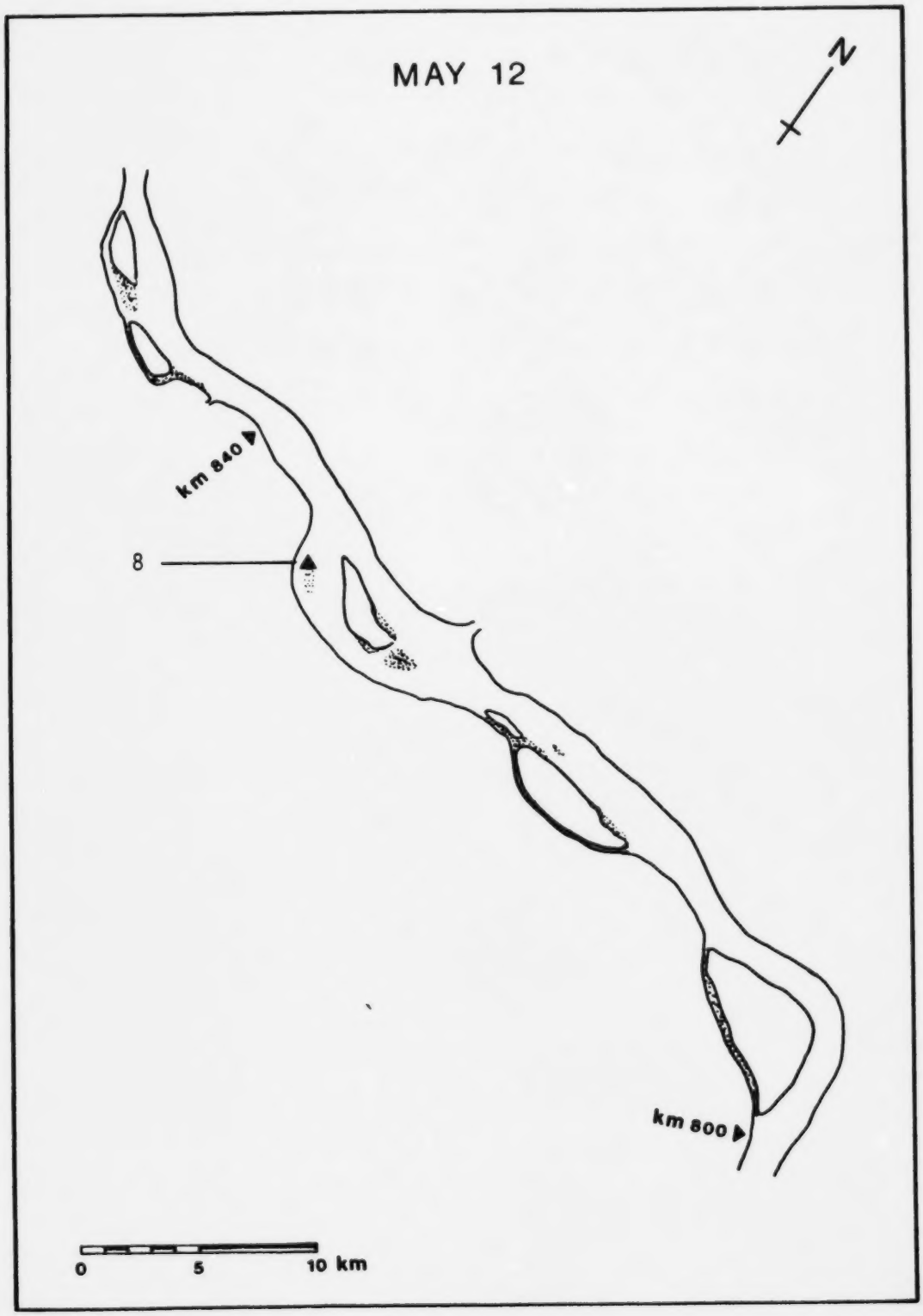
Appendix IV(b) (cont'd)



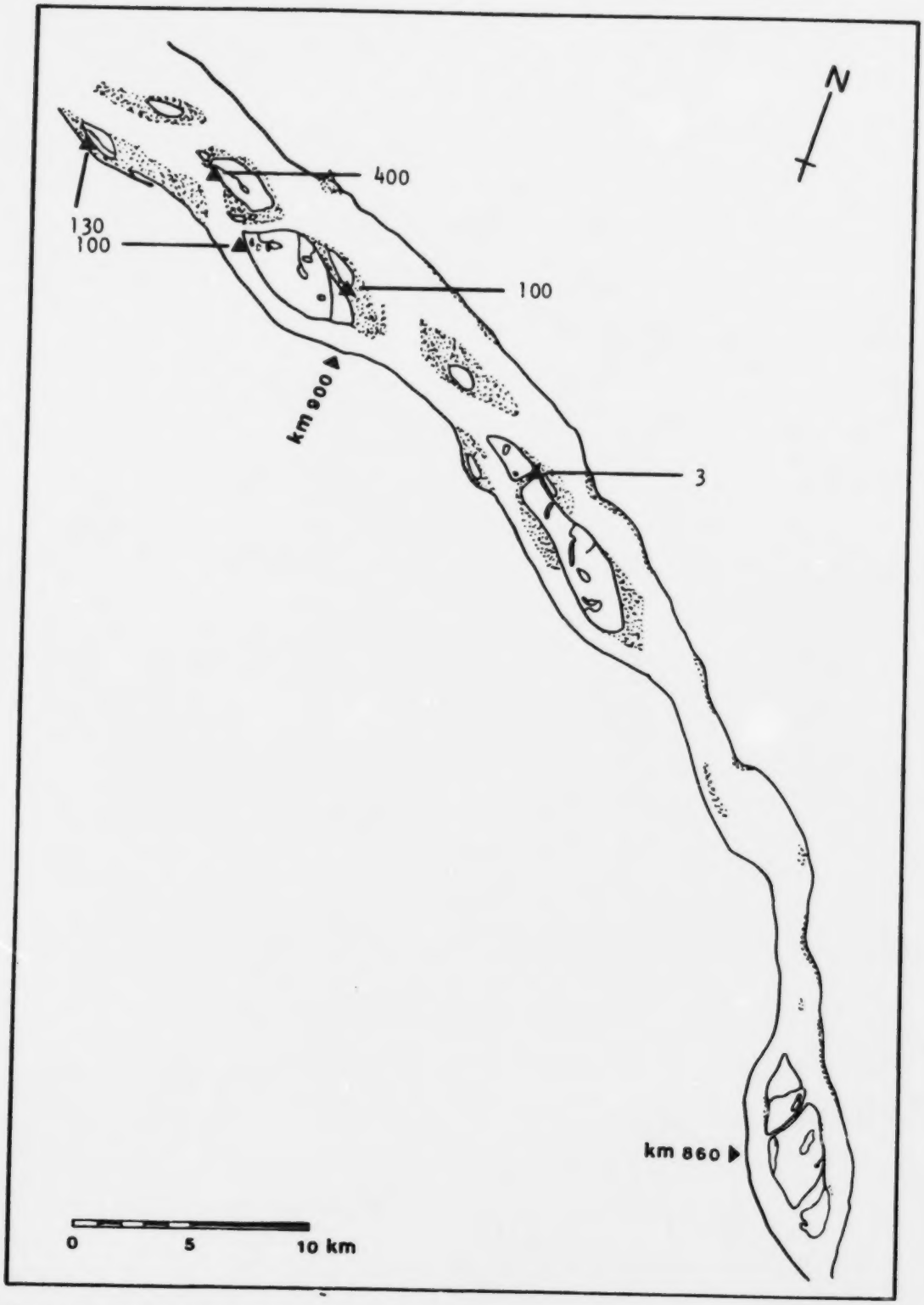
Appendix IV(b)(cont'd)



Appendix IV(b)(cont'd)



Appendix IV(c) May 12



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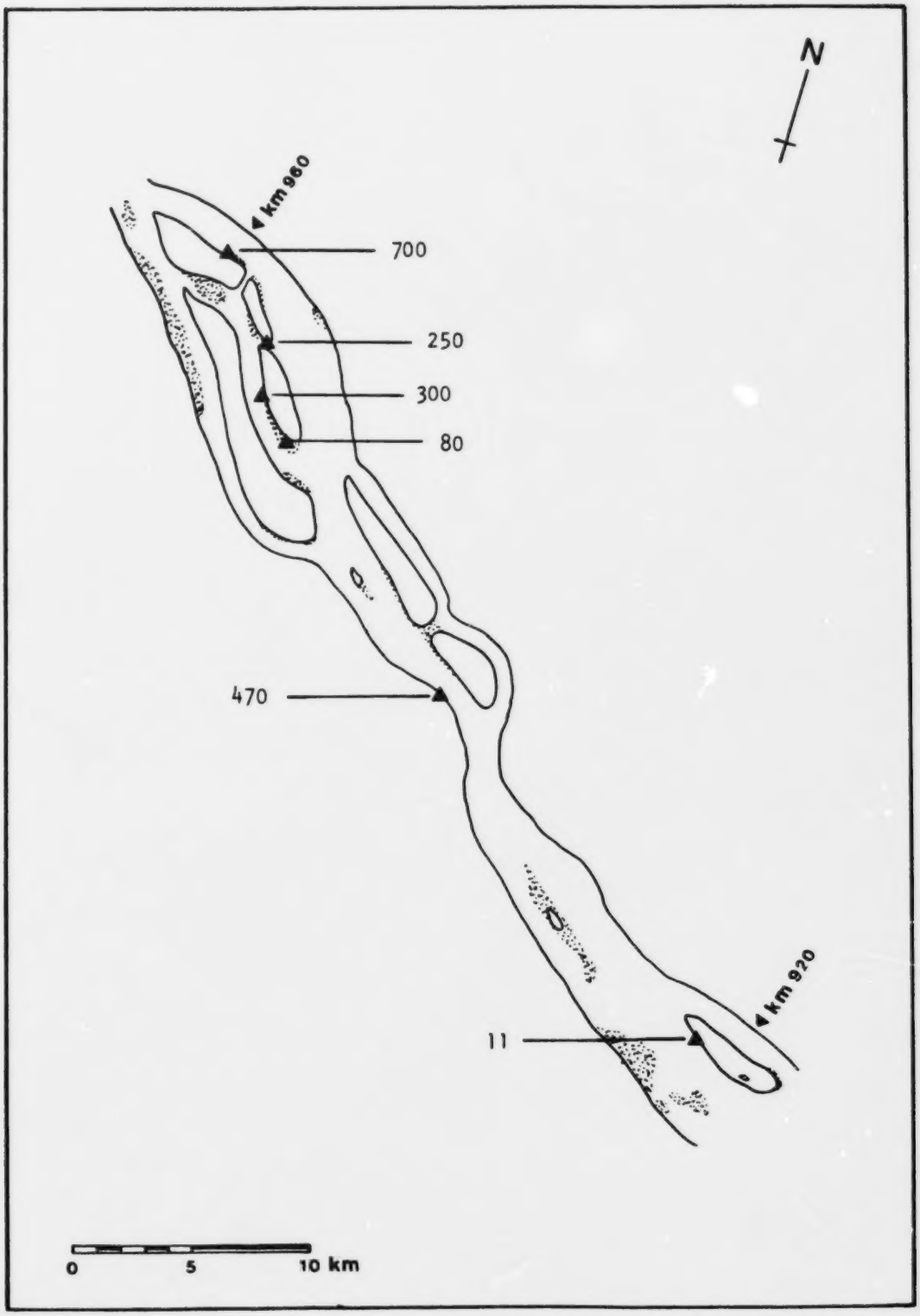

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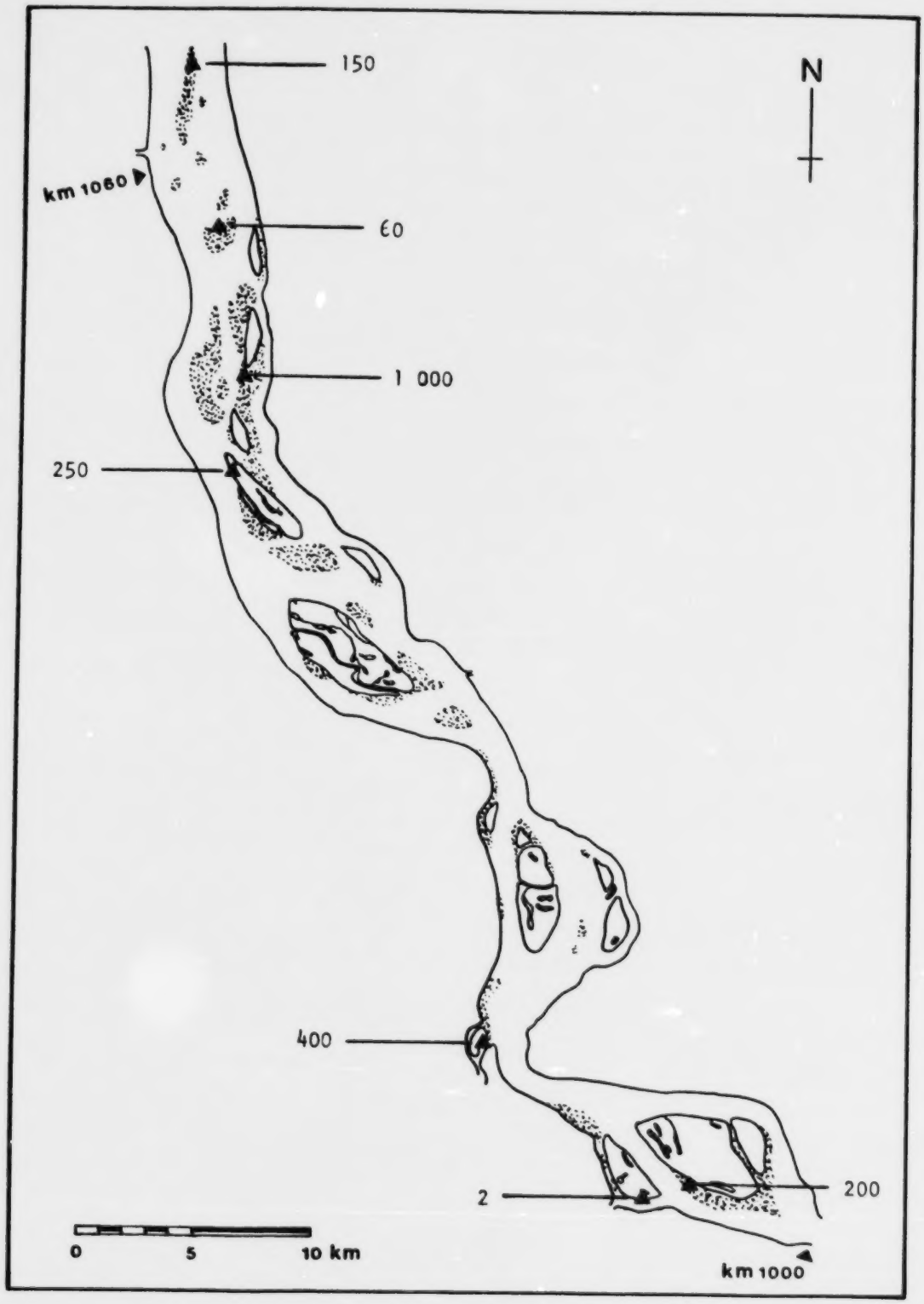

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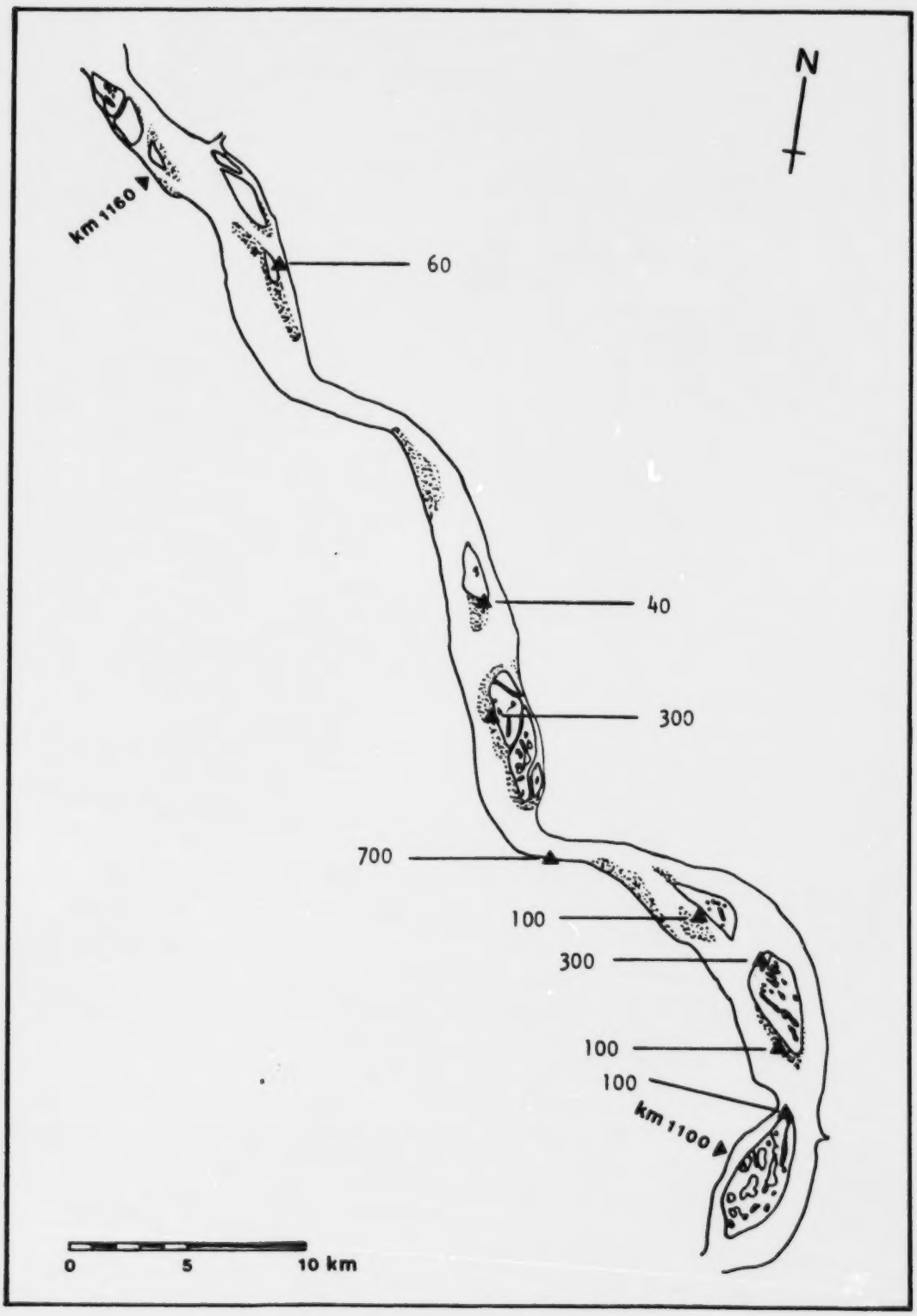

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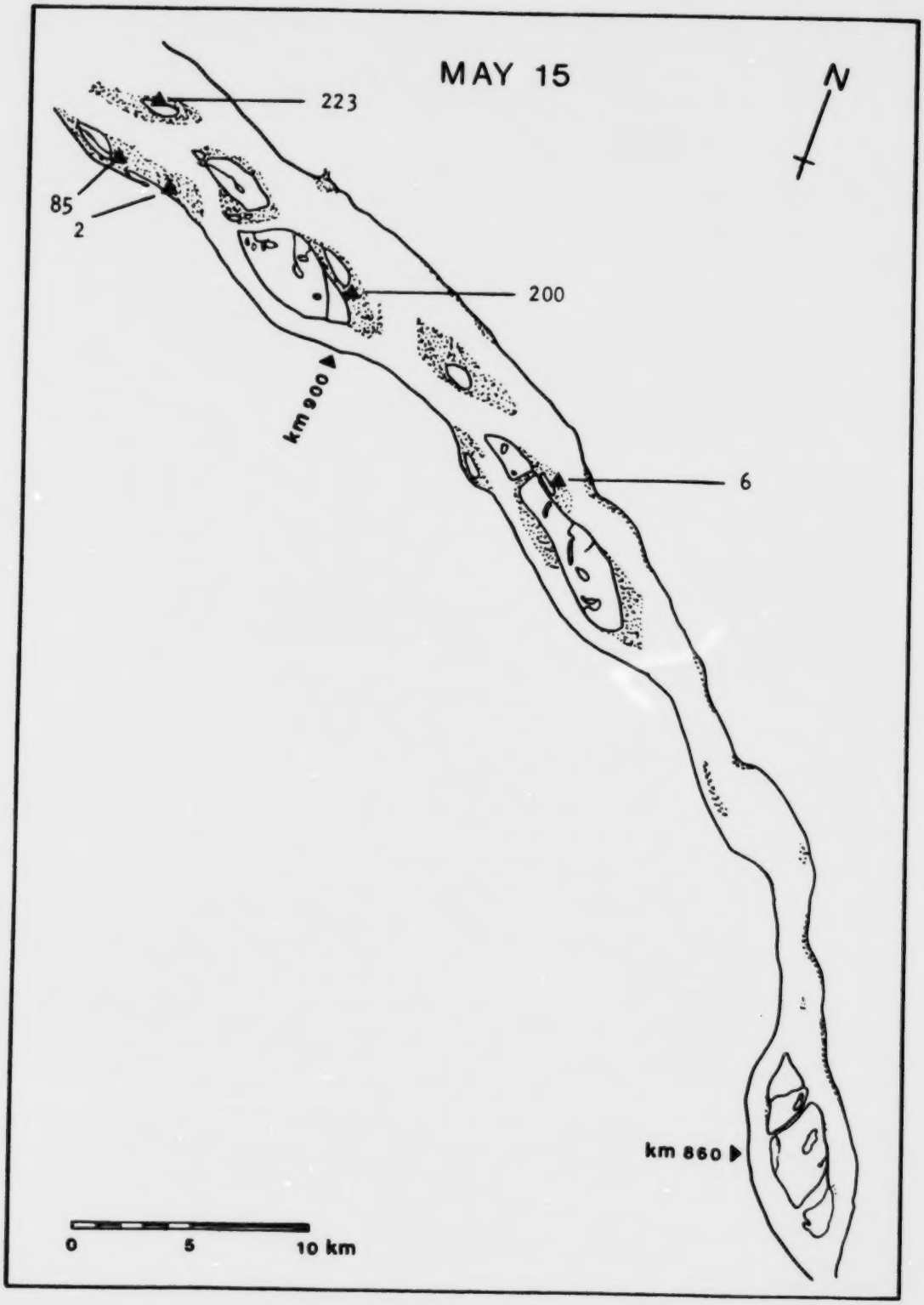
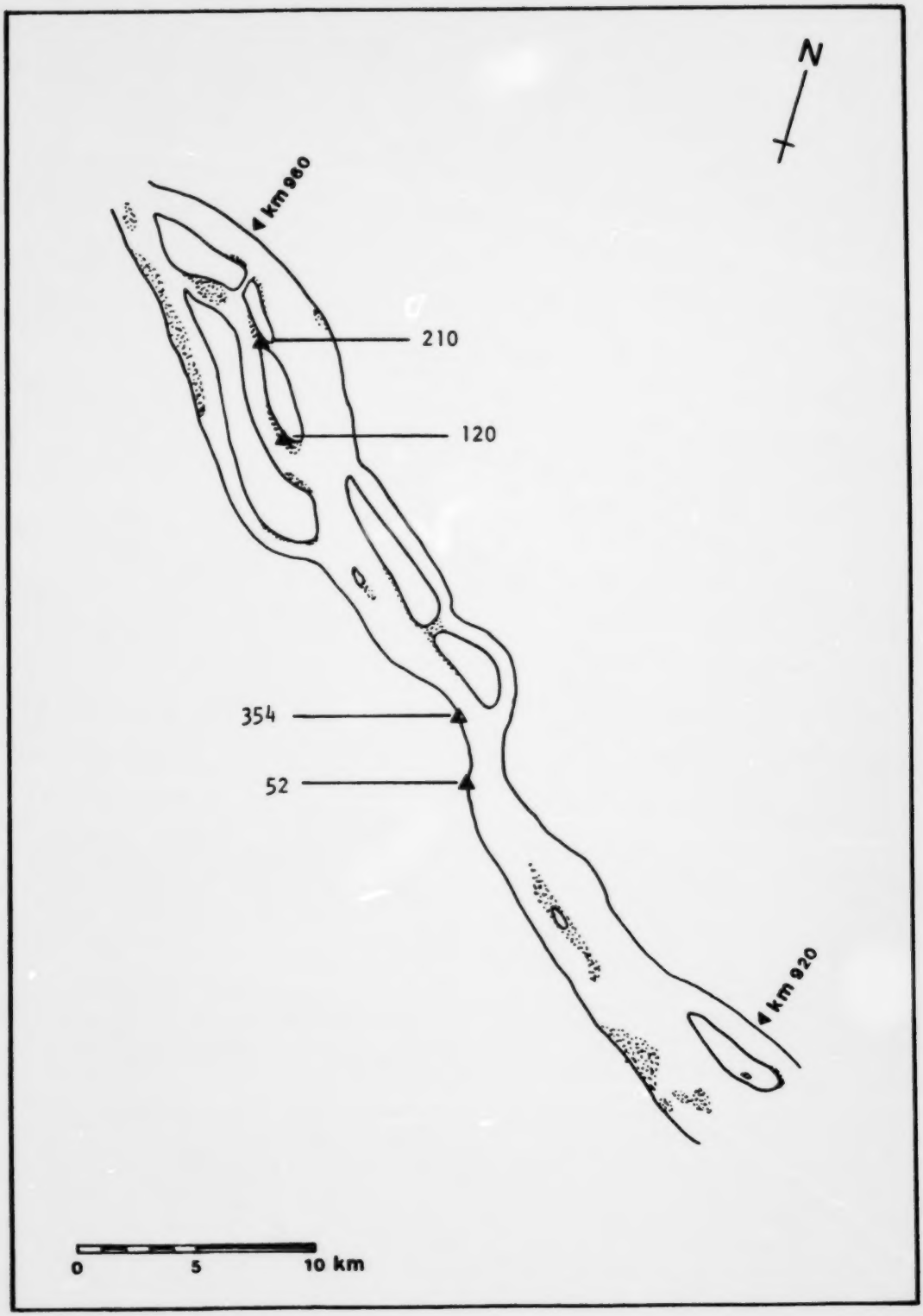
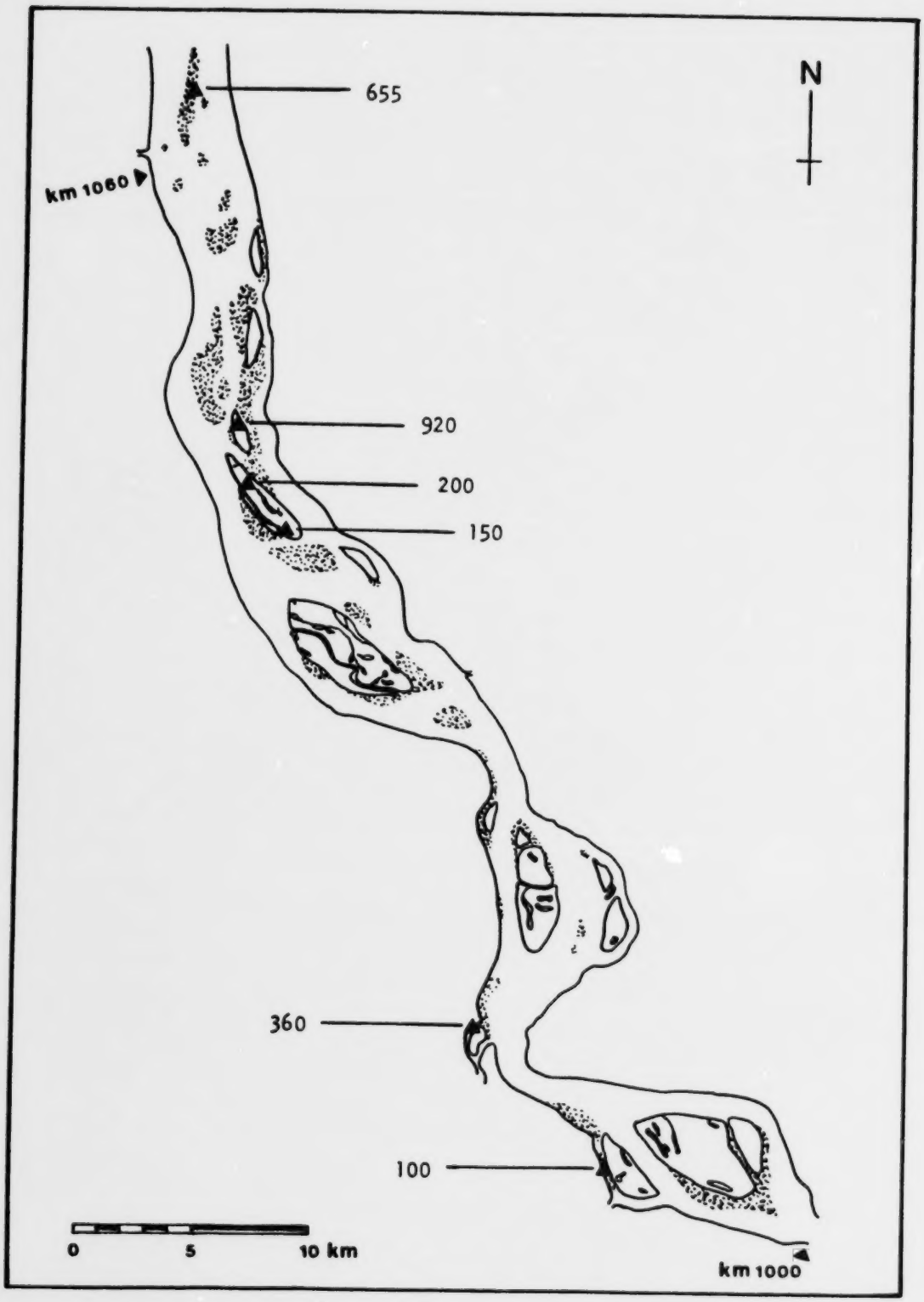


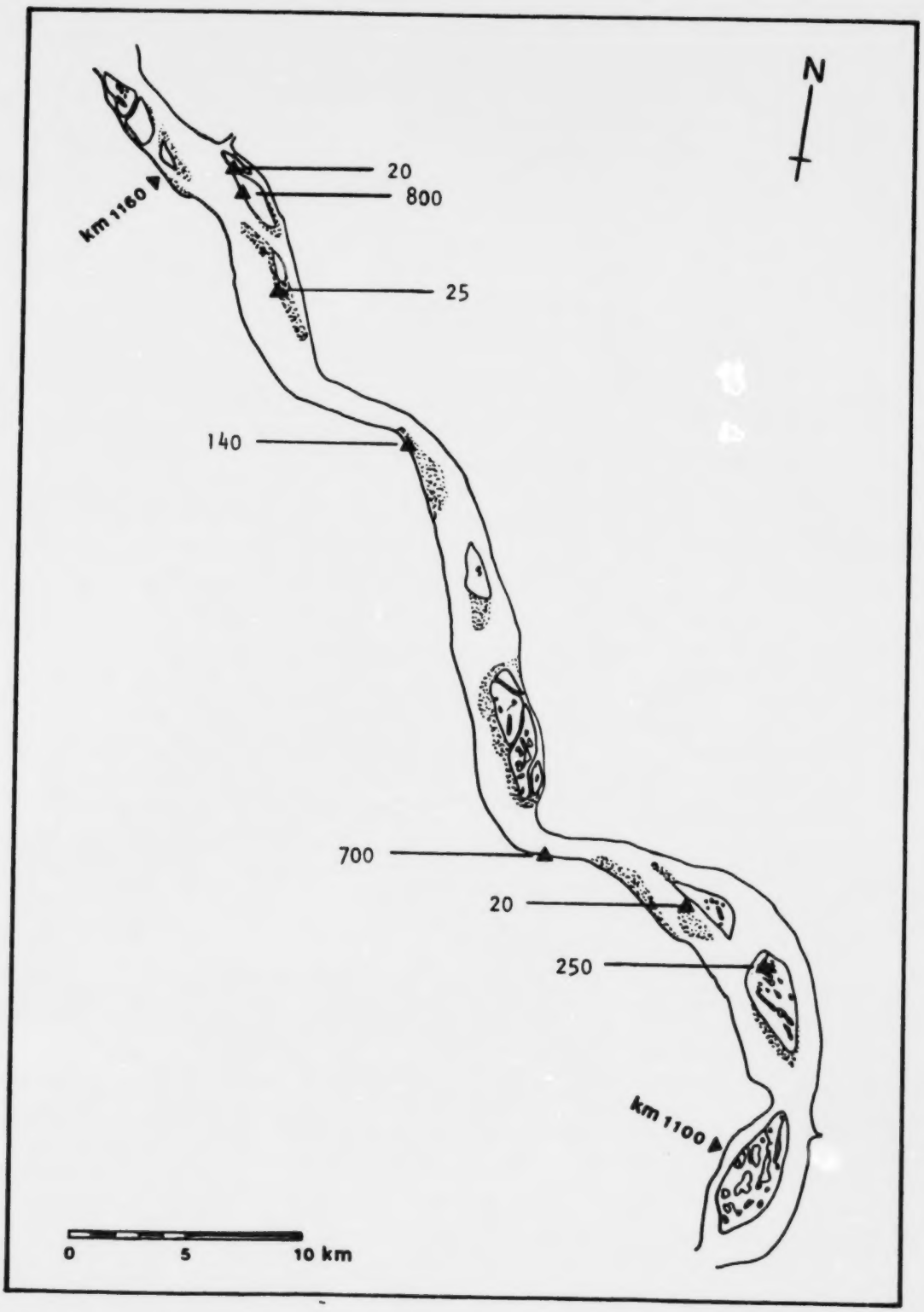
Appendix IV(d) May 15



Appendix IV(d) (cont'd)



Appendix IV(d) (cont'd)



Appendix IV(d)

Appendix V. Locations and numbers of dark geese in 1983.

Reach			May 2 [a]	May 5 [a]	May 8 [b]	May 10 [a]	May 12 [b]	May 13 [b]	May 17 [b]	May 18 [b]	May 23 [b]	May 24 [b]	May 29 [b]
Keele River km 740	-	Seagull Island km 800	380 (27) [c]	368 (35)	286 (15)	488 (9)	. [d]	.	.		.	.	.
Police Island km 800	-	Windy Island km 840	325 (23)	99 (9)	53 (3)	752 (13)	.	.	.	.	.	.	.
Little Bear River km 840	-	Prohibition Creek km 880	- [e]	10 (1)	41 (2)	144 (3)	.	.	.	.	.	.	.
Ten Mile Island km 880	-	Six Mile Island km 900	20 (1)	151 (14)	145 (8)	656 (12)	522 (19)	145 (5)	370 (6)	574 (13)	128 (3)	-	-
Bear Island km 900	-	Mac Island km 920	624 (45)	312 (30)	280 (15)	2 209 (39)	842 (30)	1 304 (49)	3 745 (59)	1 390 (32)	439 (9)	110 (6)	2 (5)
Radar Island km 920	-	Patricia Island km 960	4 (<1)	92 (9)	956 (50)	585 (10)	348 (13)	508 (19)	1 097 (17)	898 (21)	82 (2)	180 (10)	-
Trapper Creek km 960	-	Carcajou Ridge km 1000	-	-	8 (<1)	-	208 (8)	20 (1)	-	143 (3)	12 (<1)	11 (1)	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	40 (3)	12 (1)	95 (5)	362 (6)	584 (21)	239 (9)	248 (4)	283 (7)	256 (5)	152 (8)	1 (2)
Dummit Island km 1020	-	Hume Island km 1060	-	3 (<1)	30 (2)	303 (5)	170 (6)	300 (11)	531 (8)	610 (14)	1 621 (35)	89 (5)	26 (59)
Hume Island km 1060	-	Ramparts km 1100	-	-	-	50 (1)	6 (<1)	85 (3)	20 (<1)	180 (4)	124 (3)	40 (2)	12 (27)
Fort Good Hope km 1100	-	Tieda River km 1160	-	-	5 (<1)	69 (1)	81 (3)	76 (3)	340 (5)	216 (5)	2 018 (43)	1 265 ((68)	3 (7)
TOTALS			1 393	1 047	1 899	5 618	2 761	2 677	6 351	4 294	4 680	1 847	44

[a] surveyed by CWS

[b] surveyed by McCourt Management Ltd. (pers. comm.)

[c] % of total observed that day

[d] . = not surveyed

[e] - = no geese observed

Appendix VI. Locations and numbers of dark geese in 1984.[a/]

Reach			May 8	May 10	May 12	May 15
Keele River km 740	-	Seagull Island km 800	376 (7) [b/]	61 (2)	161 (4)	36 (1)
Police Island km 800	-	Windy Island km 840	212 (4)	28 (1)	122 (3)	7 (<1)
Little Bear River km 840	-	Prohibition Creek km 880	6 (<1)	8 (<1)	96 (2)	-[c/]
Ten Mile Island km 880	-	Six Mile Island km 900	395 (8)	93 (3)	184 (5)	58 (2)
Bear Island km 900	-	Mac Island km 920	667 (13)	174 (5)	320 (8)	251 (7)
Rader Island km 920	-	Patricia Island km 960	753 (14)	218 (7)	363 (9)	368 (11)
Trapper Creek km 960	-	Carcajou Ridge km 1000	20 (<1)	10 (<1)	-	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	796 (15)	339 (11)	272 (7)	160 (5)
Dummit Island km 1020	-	Hume Island km 1060	850 (16)	1 599 (50)	1 099 (28)	1 375 (41)
Hume Island km 1060	-	Ramparts km 1100	245 (5)	86 (3)	50 (1)	215 (6)
Fort Good Hope km 1100	-	Tieda River km 1160	935 (18)	574 (18)	1 322 (33)	910 (27)
TOTALS			5 255	3 190	3 989	3 380

[a/] surveyed by CWS

[b/] % of total observed that day

[c/] - = no geese observed

Appendix VII. Locations and numbers of ducks in 1983.

Reach			May 2 [a]	May 5 [a]	May 8 [b]	May 10 [a]	May 12 [b]	May 13 [b]	May 17 [b]	May 18 [b]	May 23 [b]	May 24 [b]	May 29 [b]
Keele River km 740	-	Seagull Island km 800	23 (3) [c]	88 (9)	258 (16)	903 (23)	. [d]	.	.	.	.	.	.
Police Island km 800	-	Windy Island km 840	- [e]	105 (10)	244 (15)	583 (15)	.	.	.	.	.	.	.
Little Bear River km 840	-	Prohibition Creek km 880	60 (7)	115 (11)	196 (12)	347 (9)	.	.	.	.	.	.	.
Ten Mile Island km 880	-	Six Mile Island km 900	290 (36)	339 (33)	183 (12)	580 (14)	524 (7)	602 (9)	1 134 (8)	1 475 (9)	210 (2)	685 (4)	83 (2)
Bear Island km 900	-	Mac Island km 920	307 (38)	258 (25)	596 (38)	919 (23)	2 744 (39)	2 725 (41)	1 594 (12)	5 010 (31)	1 574 (12)	815 (4)	91 (3)
Rader Island km 920	-	Patricia Island km 960	100 (12)	74 (7)	50 (3)	314 (8)	999 (14)	854 (13)	3 081 (23)	2 006 (12)	1 641 (12)	3 176 (16)	570 (17)
Trapper Creek km 960	-	Carcajou Ridge km 1000	-	-	-	34 (1)	313 (4)	256 (4)	214 (2)	336 (2)	623 (5)	2 117 (11)	51 (2)
Axel Island km 1000	-	Sans Sault Rapids km 1020	22 (3)	36 (4)	40 (3)	182 (5)	650 (9)	946 (14)	3 002 (22)	1 776 (11)	2 266 (17)	2 716 (14)	184 (5)
Dunvit Island km 1020	-	Hume Island km 1060	2 (<1)	-	12 (1)	71 (2)	960 (14)	851 (13)	2 874 (21)	3 291 (20)	3 721 (28)	4 826 (25)	824 (24)
Hume Island km 1060	-	Ramparts km 1100	9 (1)	-	-	48 (1)	173 (2)	298 (4)	898 (7)	1 179 (7)	1 095 (8)	2 476 (13)	147 (4)
Fort Good Hope km 1100	-	Tieda River km 1160	-	-	2 (<1)	24 (1)	675 (10)	148 (2)	865 (6)	1 146 (7)	2 055 (16)	2 623 (13)	1 446 (43)
TOTALS			813	1 015	1 581	4 005	7 038	6 680	13 662	16 219	13 185	19 434	3 396

[a] surveyed by CWS

[b] surveyed by McCourt Management Ltd. (pers. comm.)

[c] % of total observed that day

[d] . = not surveyed

[e] - = no ducks observed

Appendix VIII. Locations and numbers of ducks in 1984.[a/]

Reach		May 8	May 10	May 12	May 15
Keele River km 740	- Seagull Island km 800	480 (9) [b/]	236 (7)	90 (3)	56 (1)
Police Island km 800	- Windy Island km 840	432 (8)	343 (11)	222 (8)	493 (8)
Little Bear River km 840	- Prohibition Creek km 880	196 (4)	48 (1)	220 (8)	663 (11)
Ten Mile Island km 880	- Six Mile Island km 900	29 (1)	86 (3)	60 (2)	375 (6)
Bear Island km 900	- Mac Island km 920	360 (7)	200 (6)	125 (4)	498 (8)
Rader Island km 920	- Patricia Island km 960	245 (4)	107 (3)	245 (9)	680 (11)
Trapper Creek km 960	- Carcajou Ridge km 1000	40 (1)	16 (<1)	- [c/]	150 (2)
Axel Island km 1000	- Sans Sault Rapids km 1020	972 (18)	687 (21)	465 (16)	690 (11)
Dummit Island km 1020	- Hume Island km 1060	1 911 (35)	807 (25)	604 (21)	1 004 (16)
Hume Island km 1060	- Ramparts km 1100	205 (4)	155 (5)	60 (2)	440 (7)
Fort Good Hope km 1100	- Tieda River km 1160	615 (11)	544 (17)	741 (26)	1 097 (18)
TOTALS		5 485	3 229	2 832	6 146

[a/] surveyed by CWS

[b/] % of total observed that day

[c/] - = no ducks observed

Appendix IX. Locations and numbers of swans in 1983.

Reach		May 2 [a]	May 5 [a]	May 8 [b]	May 10 [a]	May 12 [b]	May 13 [b]	May 17 [b]	May 18 [b]	May 23 [b]	May 24 [b]	May 29 [b]
Keele River km 740	- Seagull Island km 800	- [c]	2 (67) [d]	-	7 (8)	. [e]	.	.	.	.	.	.
Police Island km 800	- Windy Island km 840	-	-	-	30 (32)	.	.	.	.	.	.	.
Little Bear River km 840	- Prohibition Creek km 880	-	-	-	-	.	.	.	.	.	.	.
Ten Mile Island km 880	- Six Mile Island km 900	-	-	-	5 (5)	69 (53)	35 (30)	272 (72)	347 (58)	11 (1)	-	-
Bear Island km 900	- Mac Island km 920	-	1 (33)	3 (100)	-	30 (23)	58 (50)	10 (3)	10 (2)	-	4 (1)	-
Rader Island km 920	- Patricia Island km 960	-	-	-	3 (3)	16 (12)	2 (2)	-	13 (2)	2 (<1)	20 (3)	-
Trapper Creek km 960	- Carcajou Ridge km 1000	-	-	-	-	-	-	-	8 (1)	-	2 (<1)	-
Axel Island km 1000	- Sans Sault Rapids km 1020	-	-	-	1 (1)	-	-	2 (1)	5 (1)	20 (2)	14 (2)	-
Dummit Island km 1020	- Hume Island km 1060	-	-	-	-	-	-	10 (3)	5 (1)	58 (5)	58 (10)	-
Hume Island km 1060	- Ramparts km 1100	-	-	-	-	4 (3)	13 (11)	4 (1)	-	20 (2)	-	-
Fort Good Hope km 1100	- Tieda River km 1160	-	-	-	47 (51)	10 (8)	8 (7)	79 (21)	207 (35)	1 015 (90)	487 (83)	15 (100)
TOTALS		-	3	3	93	129	116	377	595	1 126	585	15

a/ surveyed by CWS

b/ surveyed by McCourt Management Ltd. (pers. comm.)

c/ - = no swans observed

d/ % of total observed that day

e/ . = not surveyed

Appendix X. Locations and numbers of swans in 1984.[a/]

Reach			May 8	May 10	May 12	May 15
Keele River km 740	-	Seagull Island km 800	6 (27) [b/]	- [c/]	10 (5)	-
Police Island km 800	-	Windy Island km 840	-	4 (5)	10 (5)	-
Little Bear River km 840	-	Prohibition Creek km 880	-	-	-	-
Ten Mile Island km 880	-	Six Mile Island km 900	-	1 (1)	-	-
Bear Island km 900	-	Mac Island km 920	-	6 (7)	2 (1)	-
Rader Island km 920	-	Patricia Island km 960	-	-	-	-
Trapper Creek km 960	-	Carcajou Ridge km 1000	-	-	-	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	-	23 (28)	42 (22)	-
Dummit Island km 1020	-	Hume Island km 1060	11 (50)	12 (15)	27 (14)	54 (14)
Hume Island km 1060	-	Ramparts km 1100	-	30 (37)	15 (8)	75 (19)
Fort Good Hope km 1100	-	Tieda River km 1160	5 (23)	6 (7)	83 (44)	270 (68)
TOTALS			22	82	189	399

a/ surveyed by CWS

b/ % of total observed that day

c/ - = no swans observed

Appendix XI. Locations and numbers of snow geese in 1972.[a/]

Reach			May 13	May 16	May 20	May 25	May 29
Keele River km 740	-	Seagull Island km 800	.[b/]	.	.	.	.
Police Island km 800	-	Windy Island km 840	.	.	.	.	.
Little Bear River km 840	-	Prohibition Creek km 880	.	.	.	.	.
Ten Mile Island km 880	-	Six Mile Island km 900	22 416 (53)[c/]	9 725 (20)	681 (4)	-[d/]	-
Bear Island km 900	-	Mac Island km 920	12 232 (29)	25 650 (53)	3 045 (20)	286 (4)	182 (86)
Rader Island km 920	-	Patricia Island km 960	1 573 (4)	5 438 (11)	881 (6)	25 (<1)	-
Trapper Creek km 960	-	Carcajou Ridge km 1000	-	-	-	2 (<1)	-
Axel Island km 1000	-	Sans Sault Rapids km 1020	-	-	-	33 (1)	-
Dummit Island km 1020	-	Hume Island km 1060	6 323 (15)	6 948 (14)	4 887 (32)	1 227 (17)	30 (14)
Hume Island km 1060	-	Ramparts km 1100	.	-	1 343 (9)	67 (1)	-
Fort Good Hope km 1100	-	Tieda River km 1160	.	1 050 (2)	4 535 (30)	5 529 (17)	-
TOTALS			42 544	48 811	15 372	7 169	212

a/ Campbell and Shepard (1973)

b/ . = not surveyed

c/ % of total observed that day

d/ - = no snow geese observed

Appendix XII. Locations and numbers of snow geese in 1980.[a/]

Reach			May 2	May 4	May 5	May 9	May 14	May 15	May 19
Keele River km 740	-	Seagull Island km 800	.[b/]	10 600 (62)[c/]	.	11 400 (44)	.	.	.
Police Island km 800	-	Windy Island km 840	-[d/]	-	.	1 075 (4)	.	.	.
Little Bear River km 840	-	Prohibition Creek km 880	-	-	.	800 (3)	.	.	.
Ten Mile Island km 880	-	Six Mile Island km 900	5 500 (60)[e/]	5 500 (32)	.	12 700 (49)	.	4 700 (24)	.
Bear Island km 900	-	Mac Island km 920	3 700 (40)[f/]	900 (6)[g/]	7 000 (100)	.	4 600 (100)[f/]	5 560 (28)	-
Rader Island km 920	-	Patricia Island km 960	.	.	.	.	.	4 025 (17)	.
Trapper Creek km 960	-	Carcajou Ridge km 1000	.	.	.	.	.	.	.
Axel Island km 1000	-	Sans Sault Rapids km 1020	.	.	.	.	.	.	.
Dummit Island km 1020	-	Hume Island km 1060	.	.	.	.	.	250 (1)	.
Hume Island km 1060	-	Ramparts km 1100	.	.	.	.	.	.	.
Fort Good Hope km 1100	-	Tieda River km 1160	.	.	.	.	.	5 400 (23)	.
TOTALS			9 200	17 000	7 000	25 975	4 600	19 985	-

a/ R. Webb Environmental Services Ltd. (1980)

b/ . = not surveyed

c/ % of total observed that day

d/ - = no snow geese observed

e/ Ten Mile Island only

f/ Goose Island only

g/ Bear Island only

Appendix XIII. Locations and numbers of snow geese in 1981.[a/]

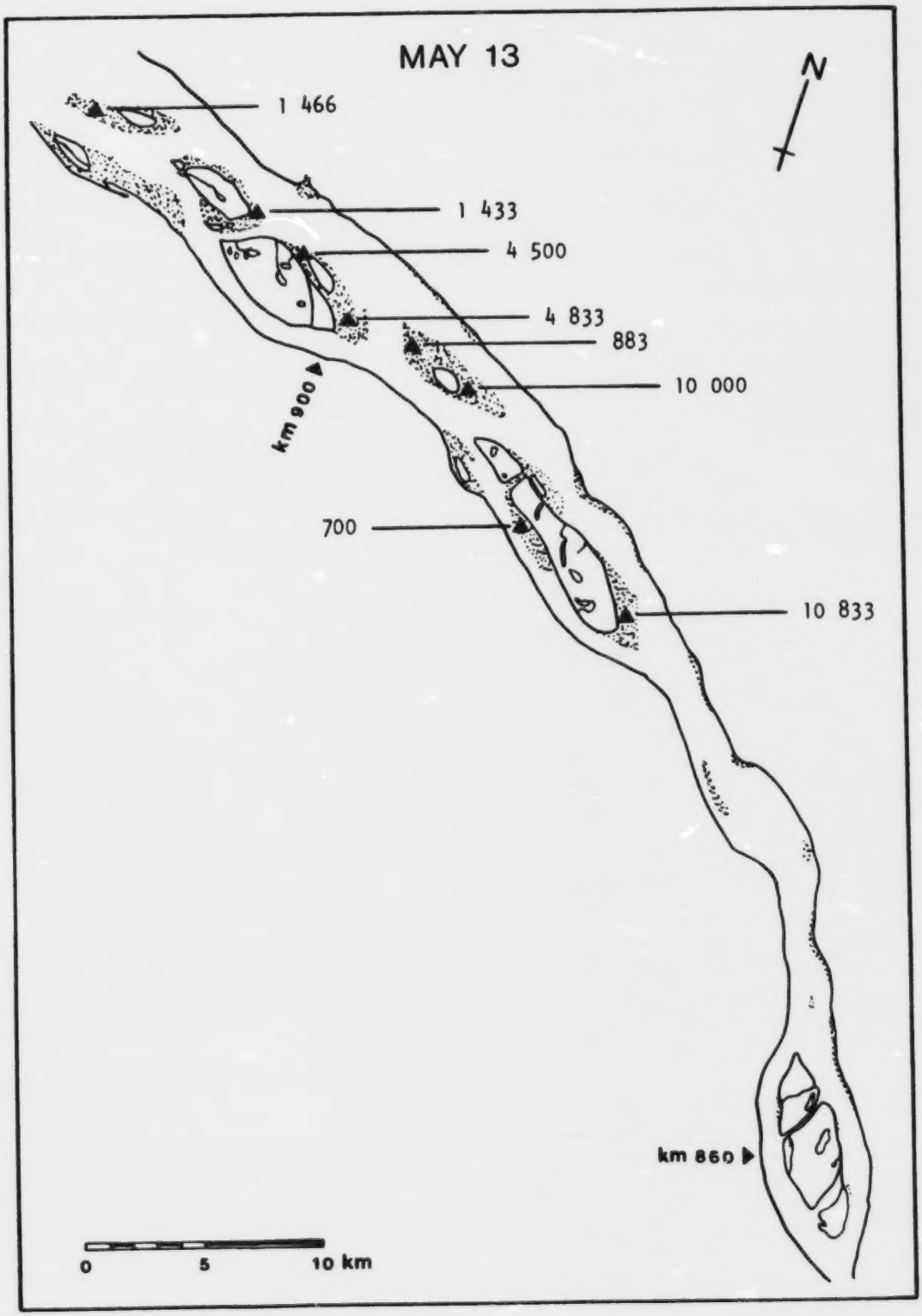
Reach		May 2	May 5	May 7	May 9	May 10	May 13
Keele River km 740	- Seagull Island km 800	-[b/]	.[c/]	.	.	.	.
Police Island km 800	- Windy Island km 840	-	.	.	.	.	.
Little Bear River km 840	- Prohibition Creek km 880	-	.	.	.	.	.
Ten Mile Island km 880	- Six Mile Island km 900	20 (3)[d/]	.	25 (5)	-	-	-
Bear Island km 900	- Mac Island km 920	15 (2)	500 (40)	500 (95)	35 (100)	32 (100)	-
Rader Island km 920	- Patricia Island km 960	400 (65)	750 (60)	-	.	-	5 (100)
Trapper Creek km 960	- Carcajou Ridge km 1000	-	-	-	.	-	-
Axel Island km 1000	- Sans Sault Rapids km 1020	-	-	-	.	-	-
Dummit Island km 1020	- Hume Island km 1060	180 (29)	.	.	.	.	.
Hume Island km 1060	- Ramparts km 1100	-	.	.	.	.	.
Fort Good Hope km 1100	- Tieda River km 1160	-	.	.	.	.	.
TOTALS		615	1 250	525	35	32	5

a/ R. Webb Environmental Services Ltd. (1983)

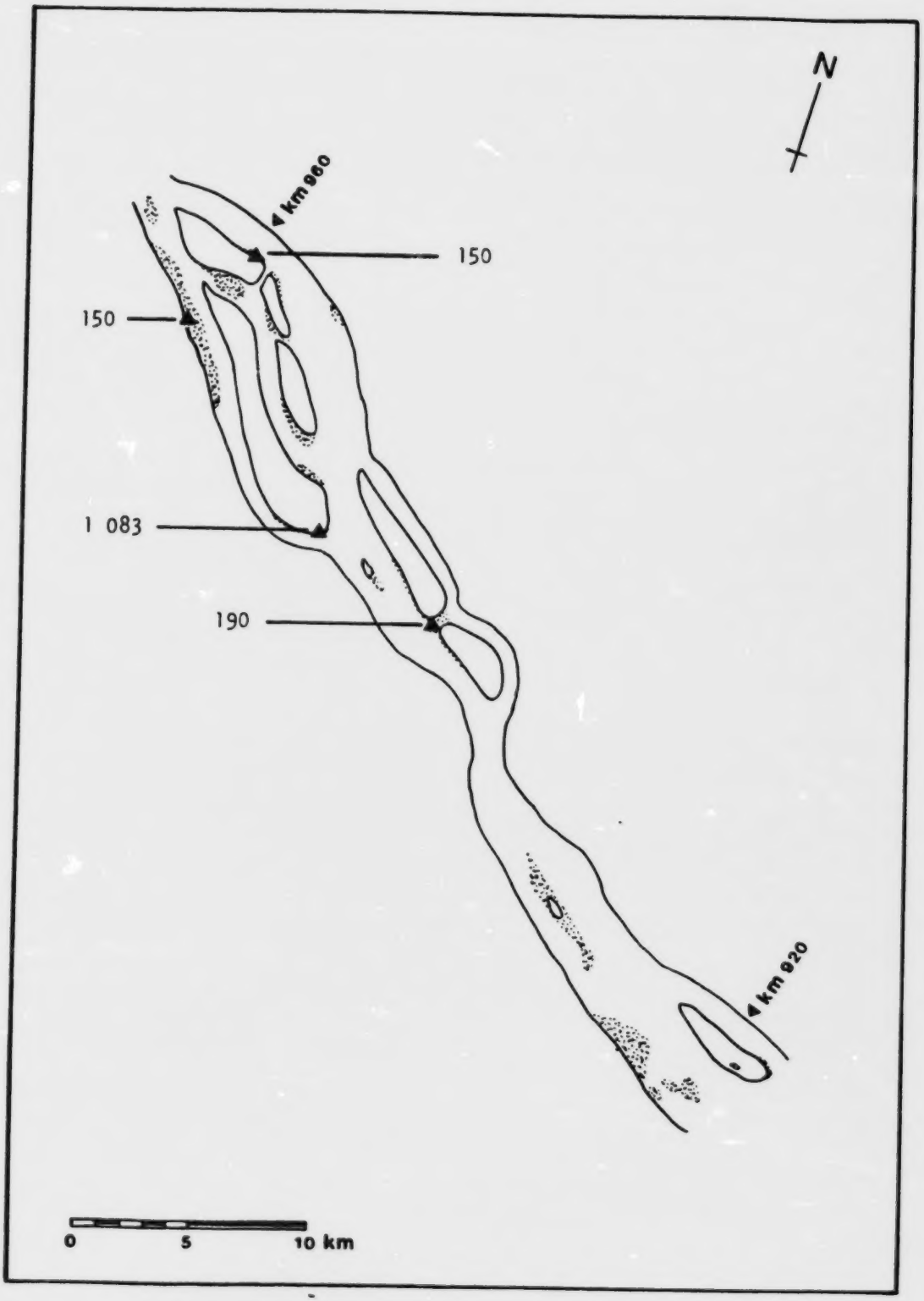
b/ - = no snow geese observed

c/ . = not surveyed

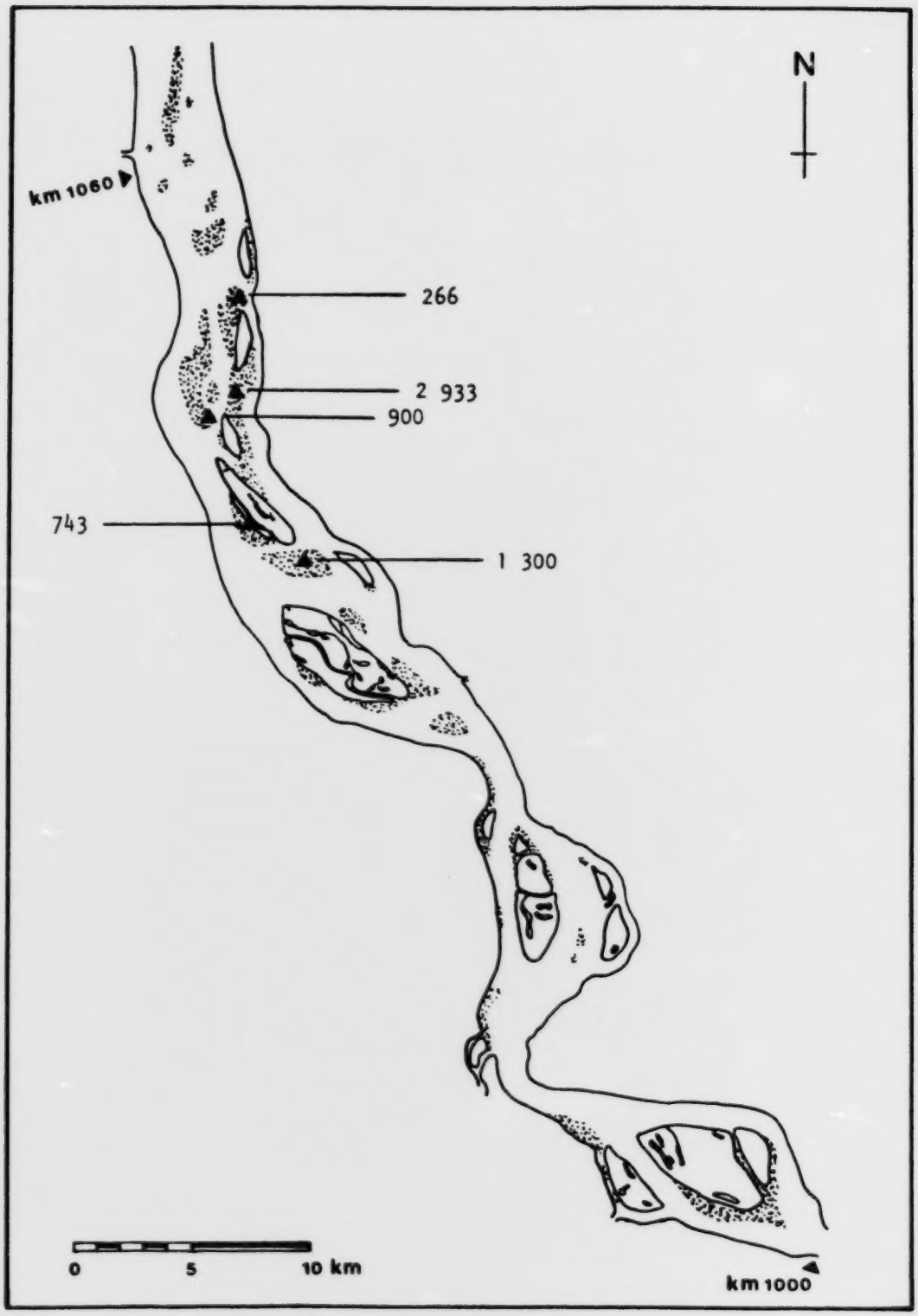
d/ % of total observed that day



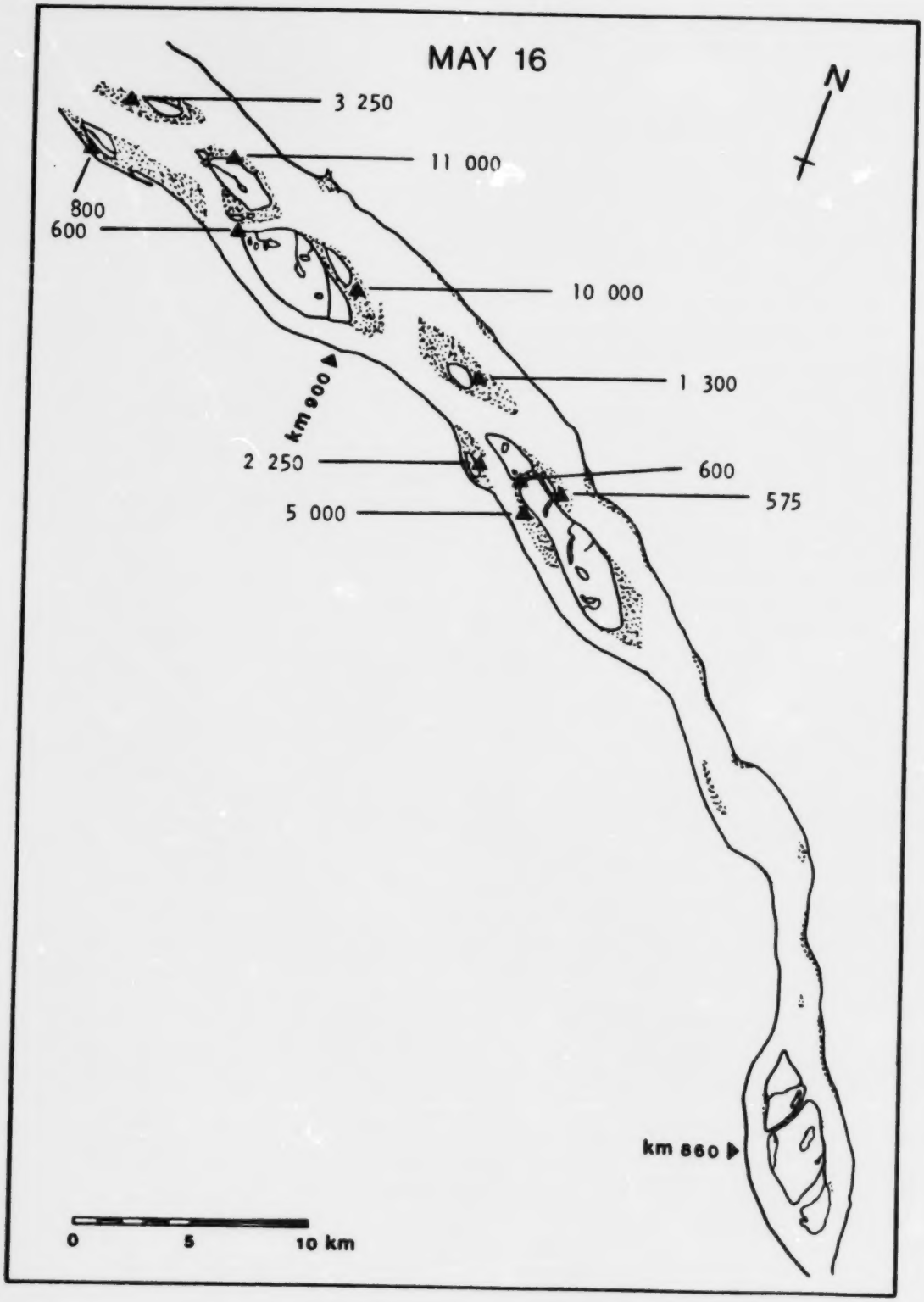
Appendix XIV: Locations of snow goose sightings in 1972.
(a) May 13



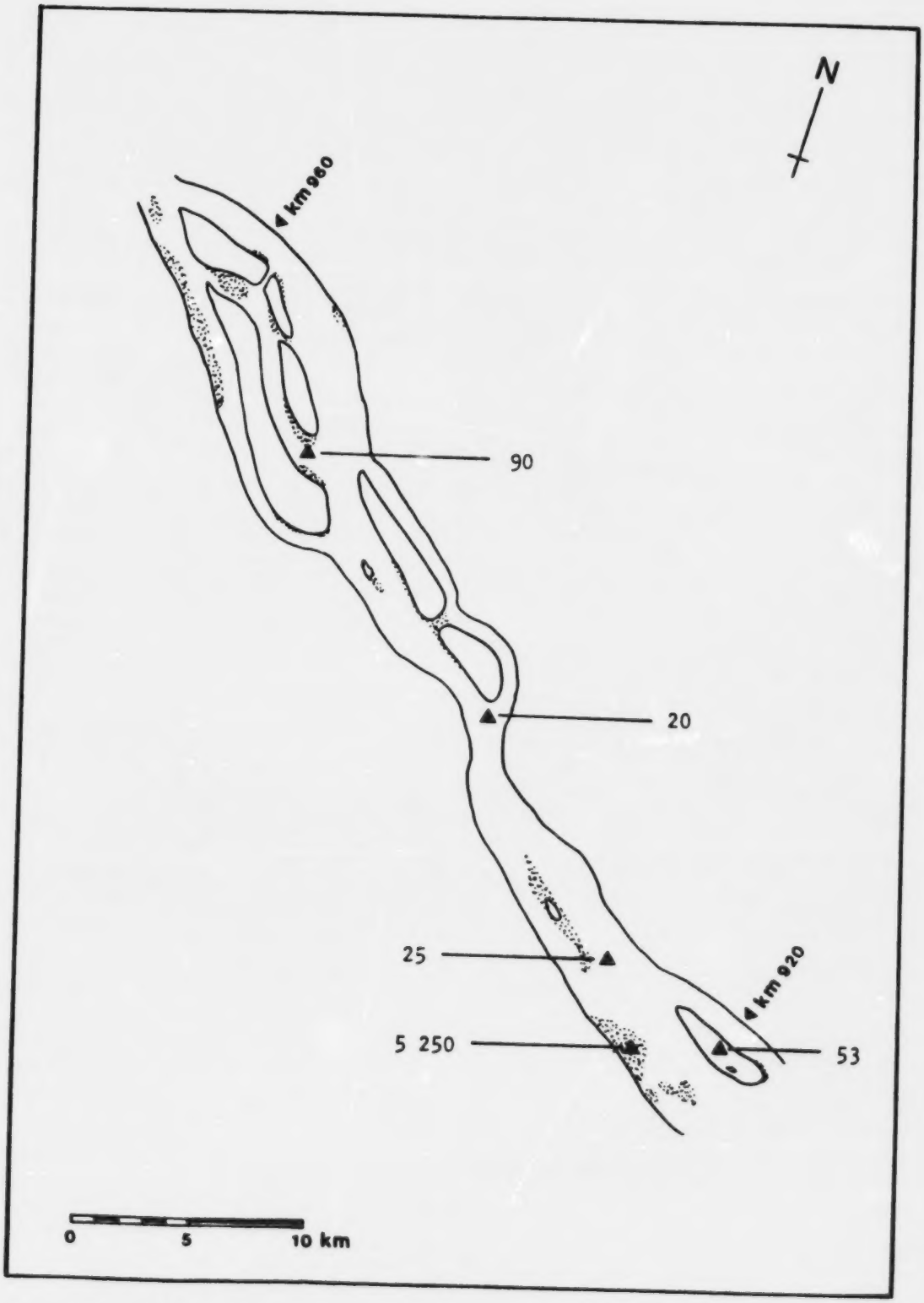
Appendix XIV (a) (cont'd)



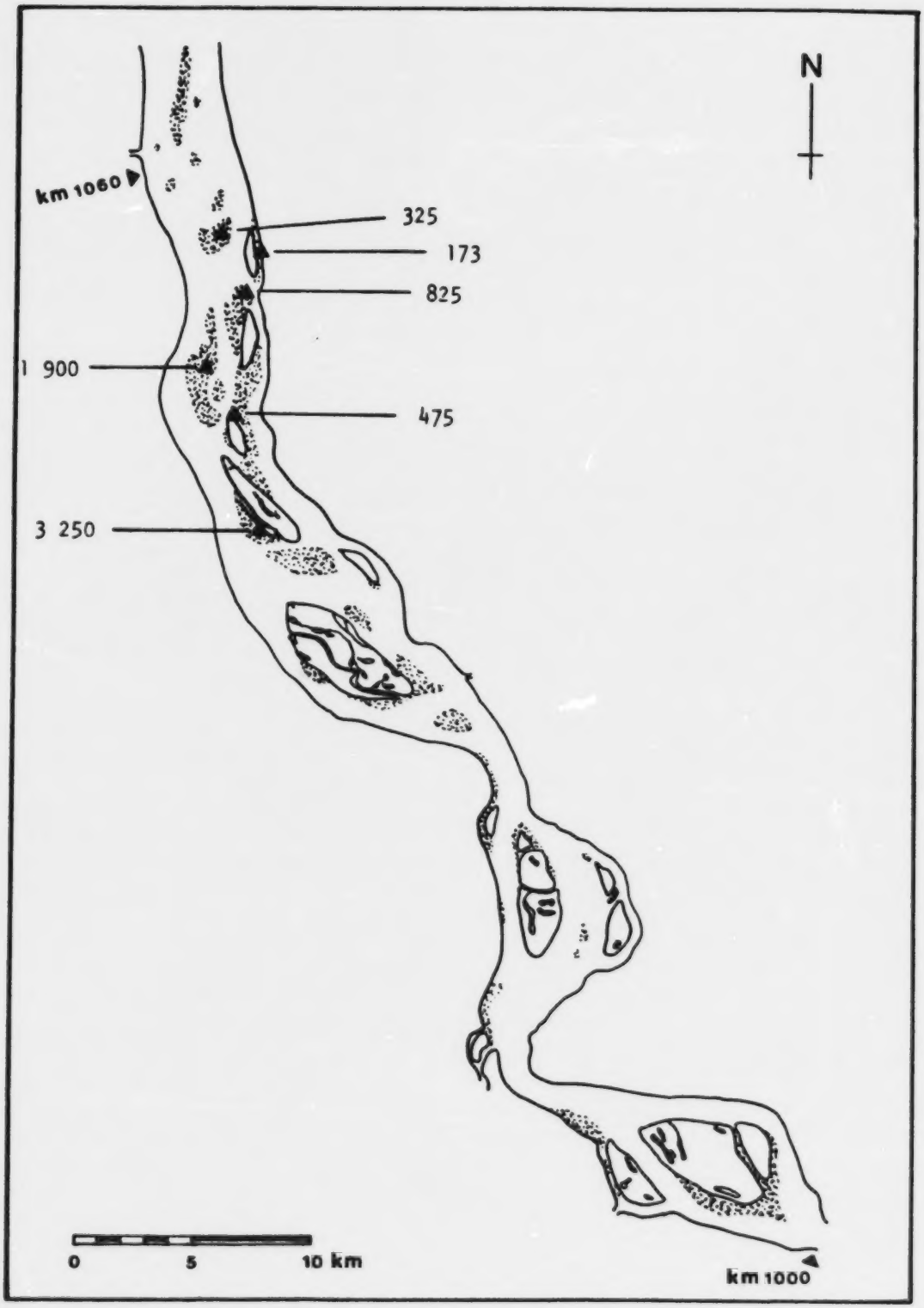
Appendix XIV(a)(cont'd)



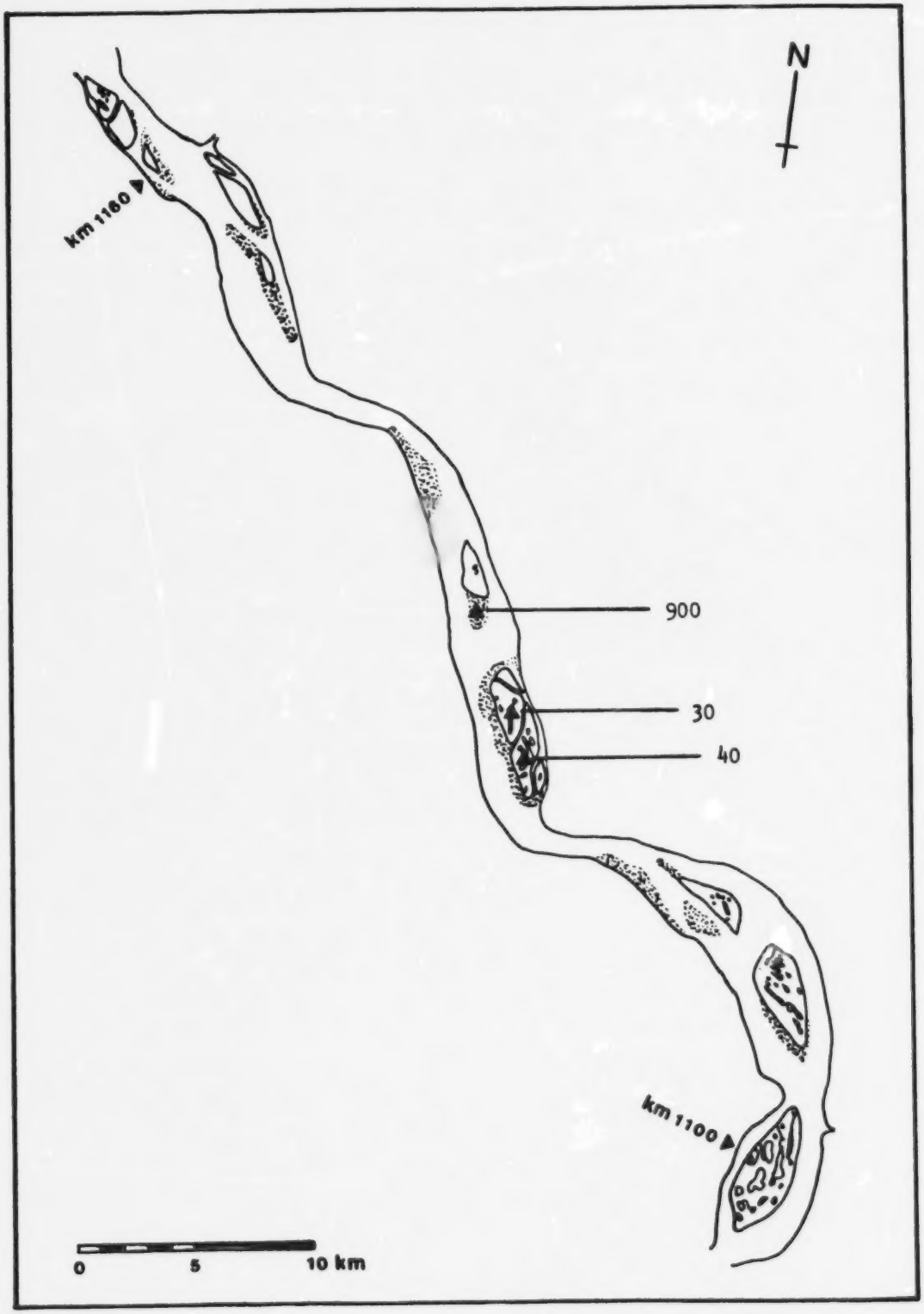
Appendix XIV(b) May 16



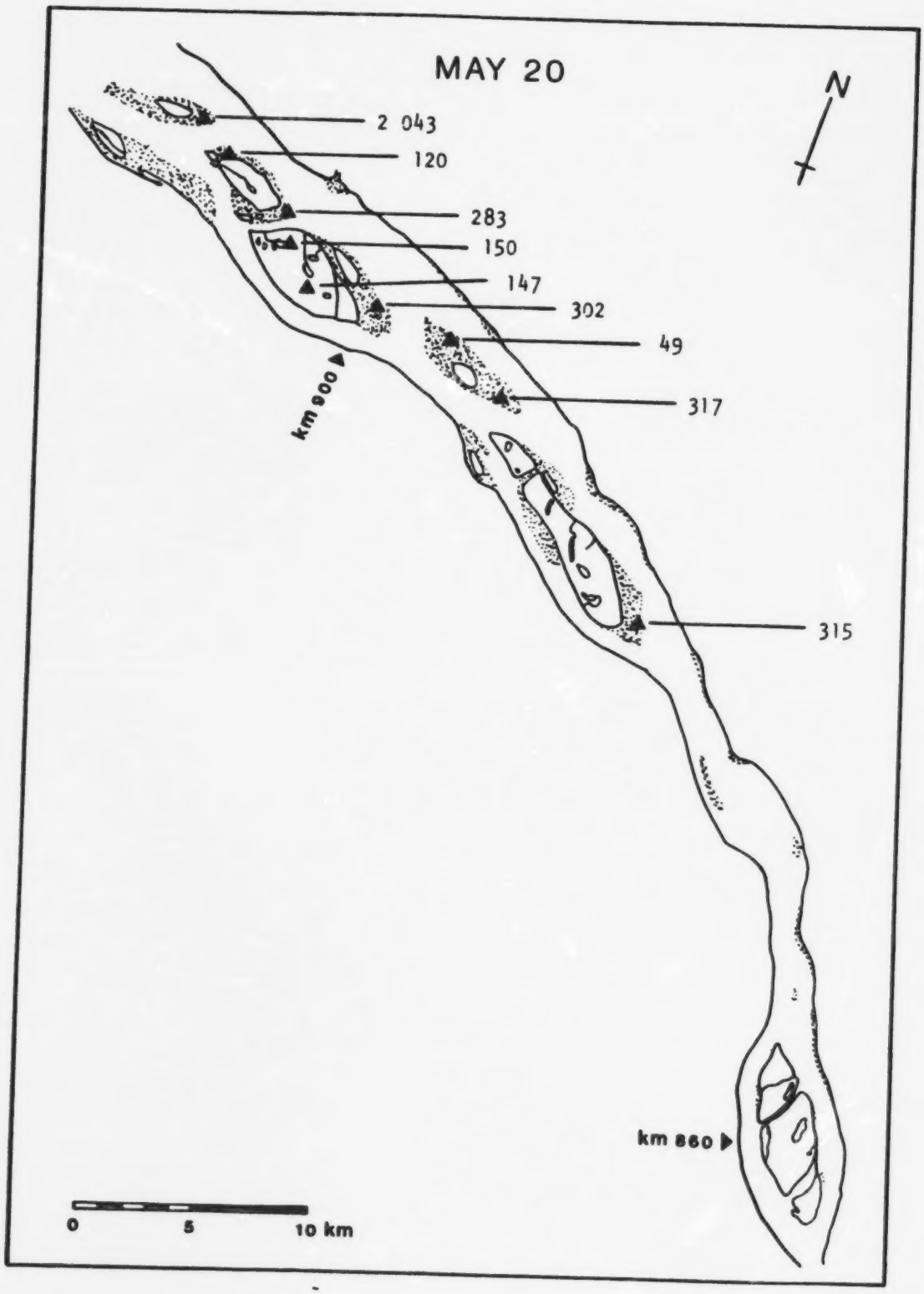
Appendix XIV(b)(cont'd)



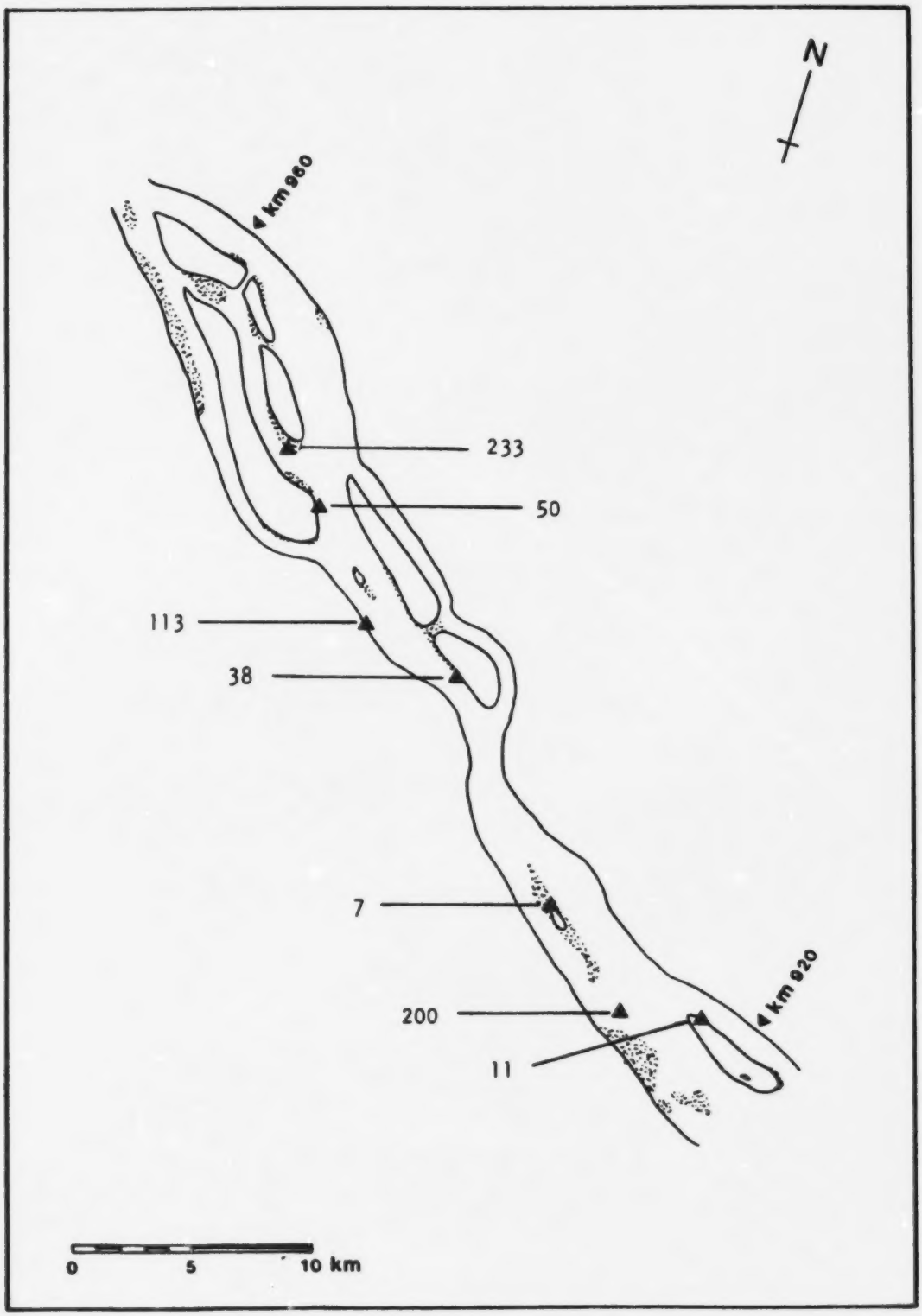
Appendix XIV(b)(cont'd)



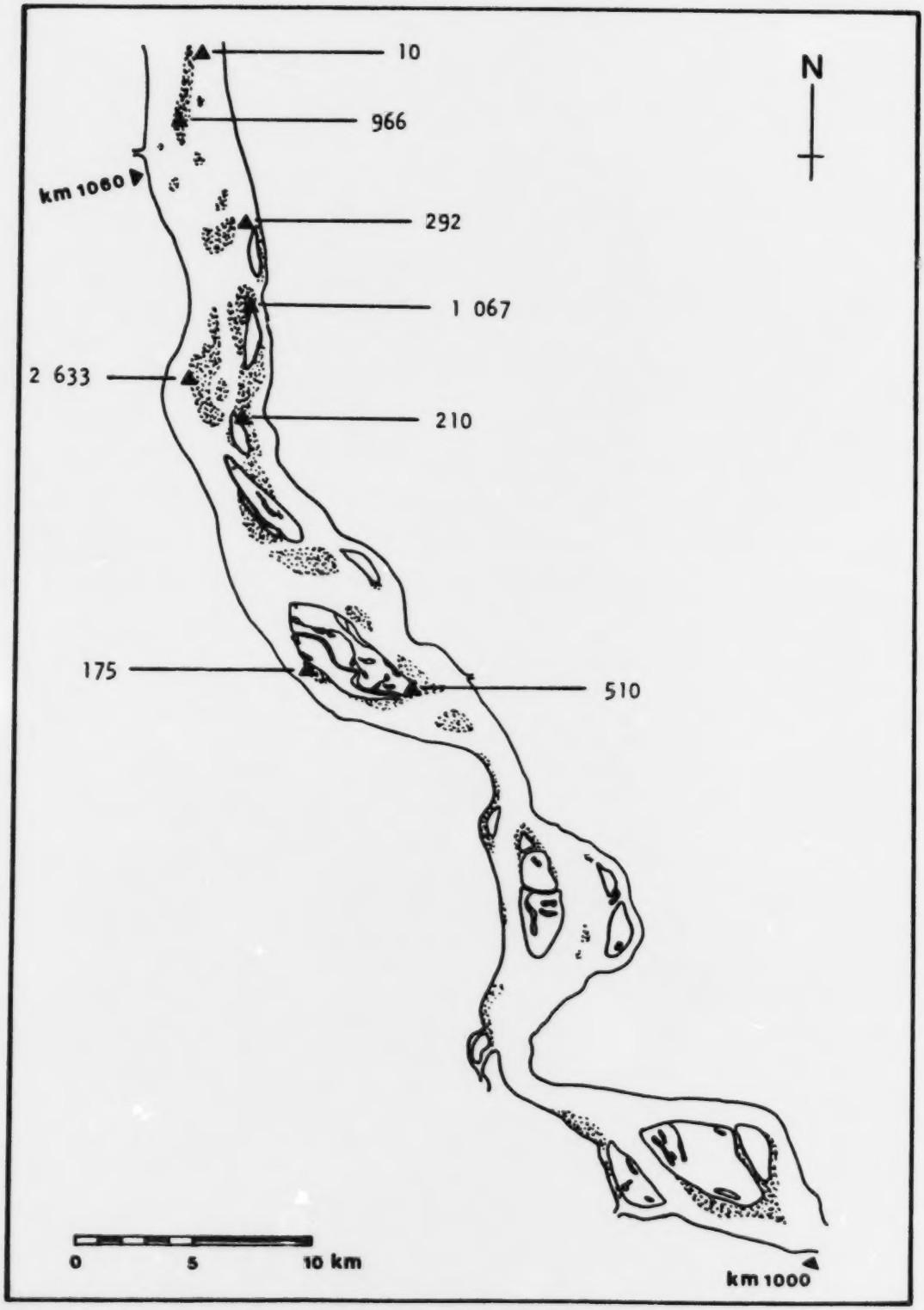
Appendix XIV(b)(cont'd)



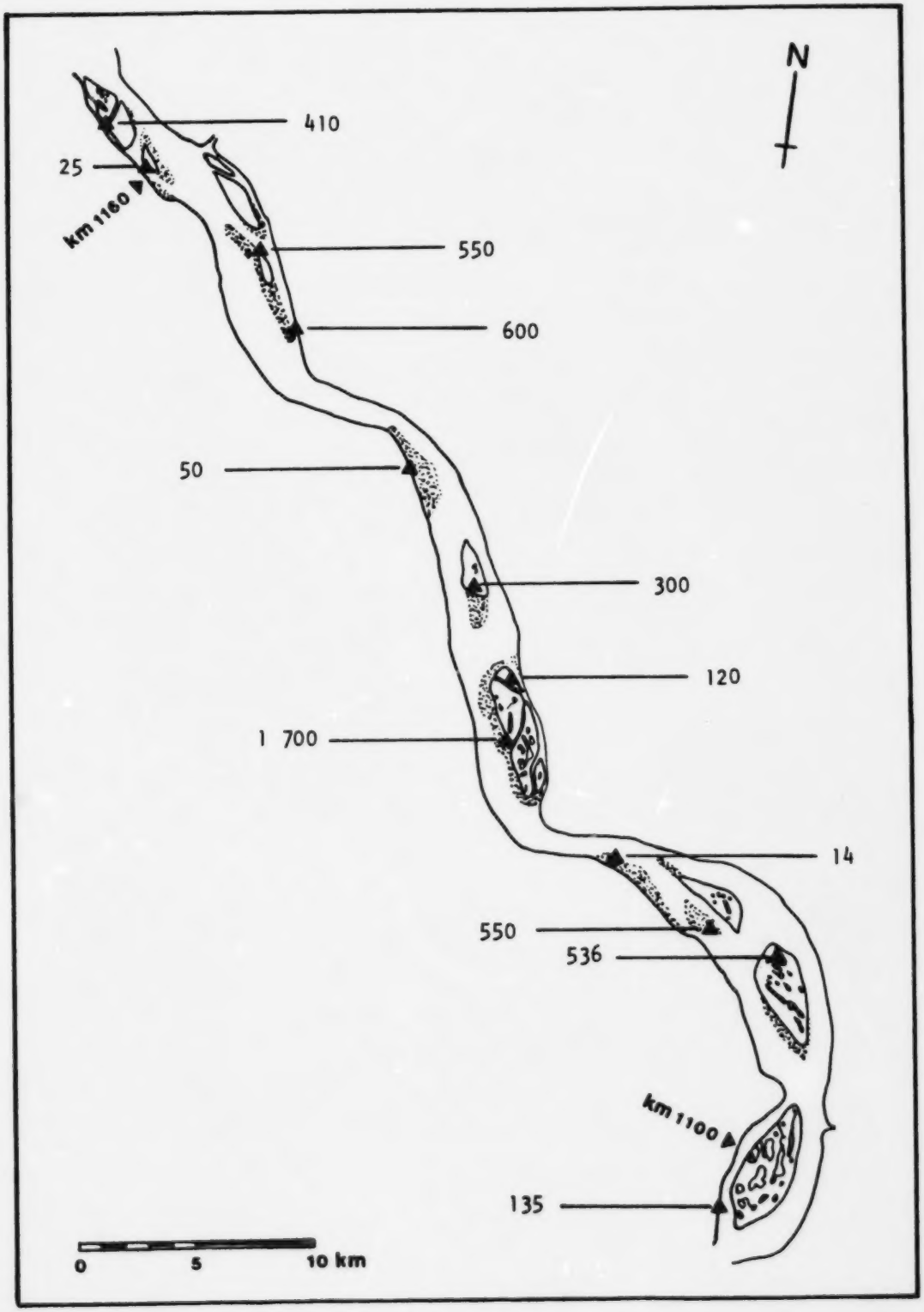
Appendix XIV(c) May 20



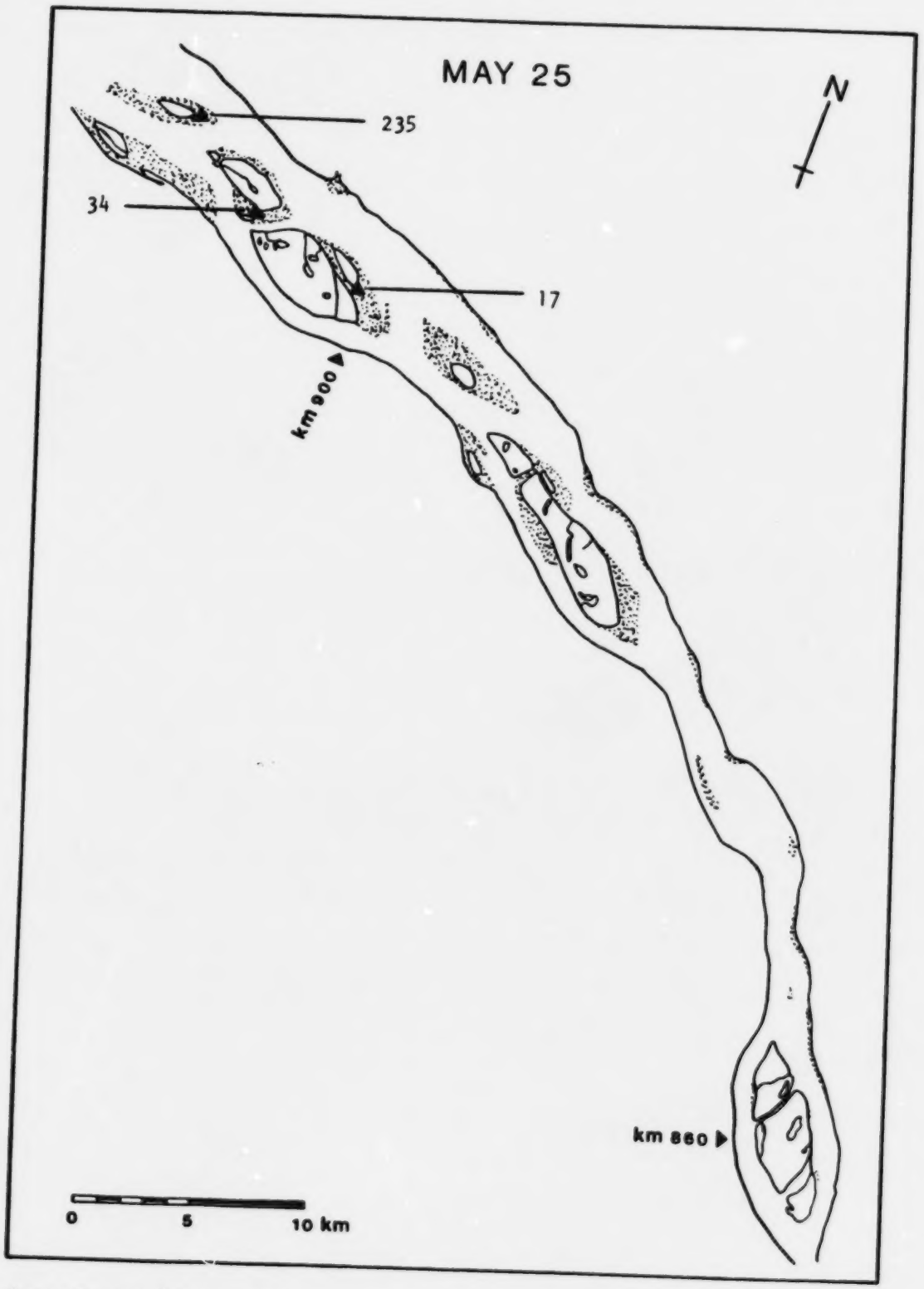
Appendix XIV(c)(cont'd)



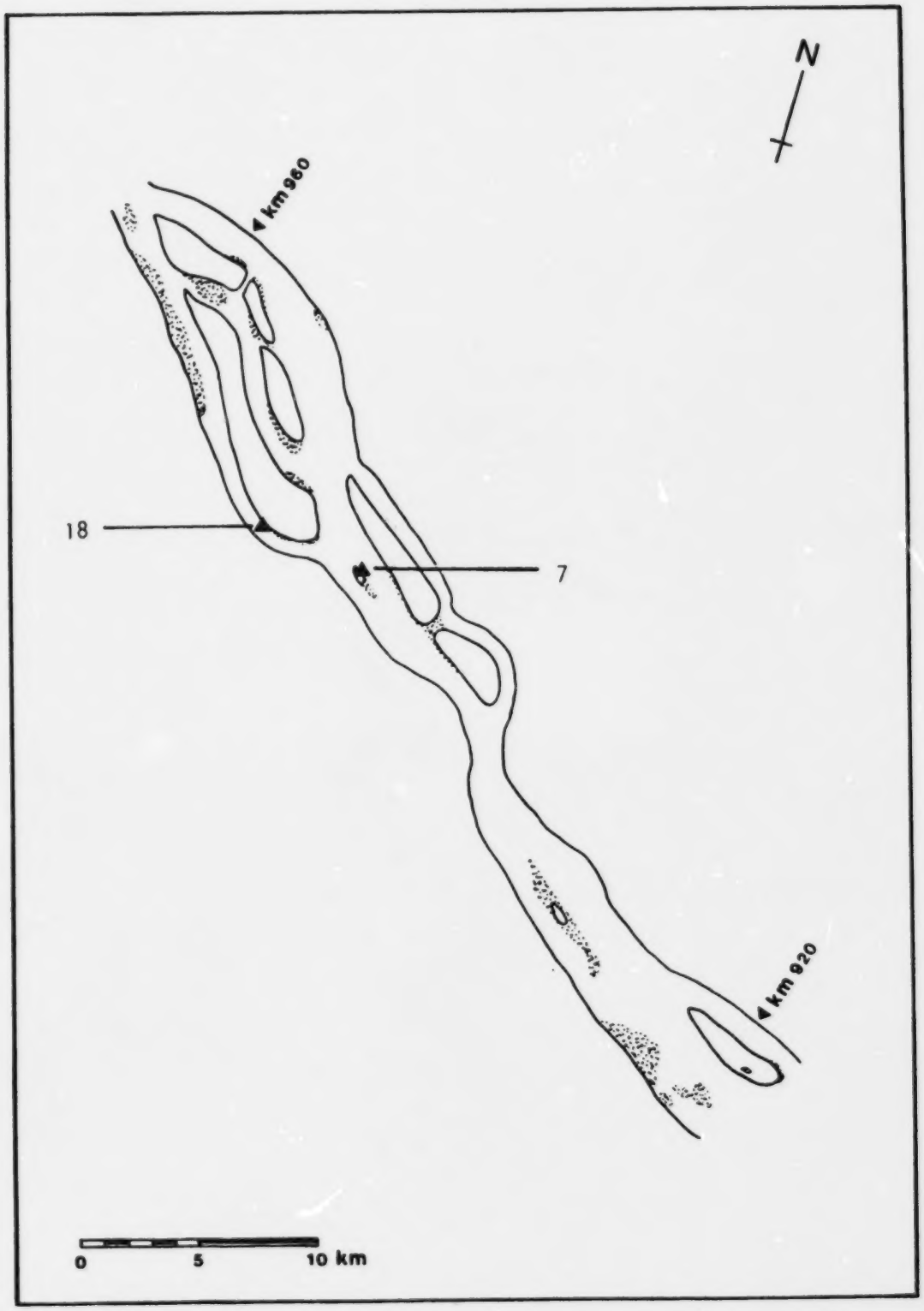
Appendix XIV(c)(cont'd)



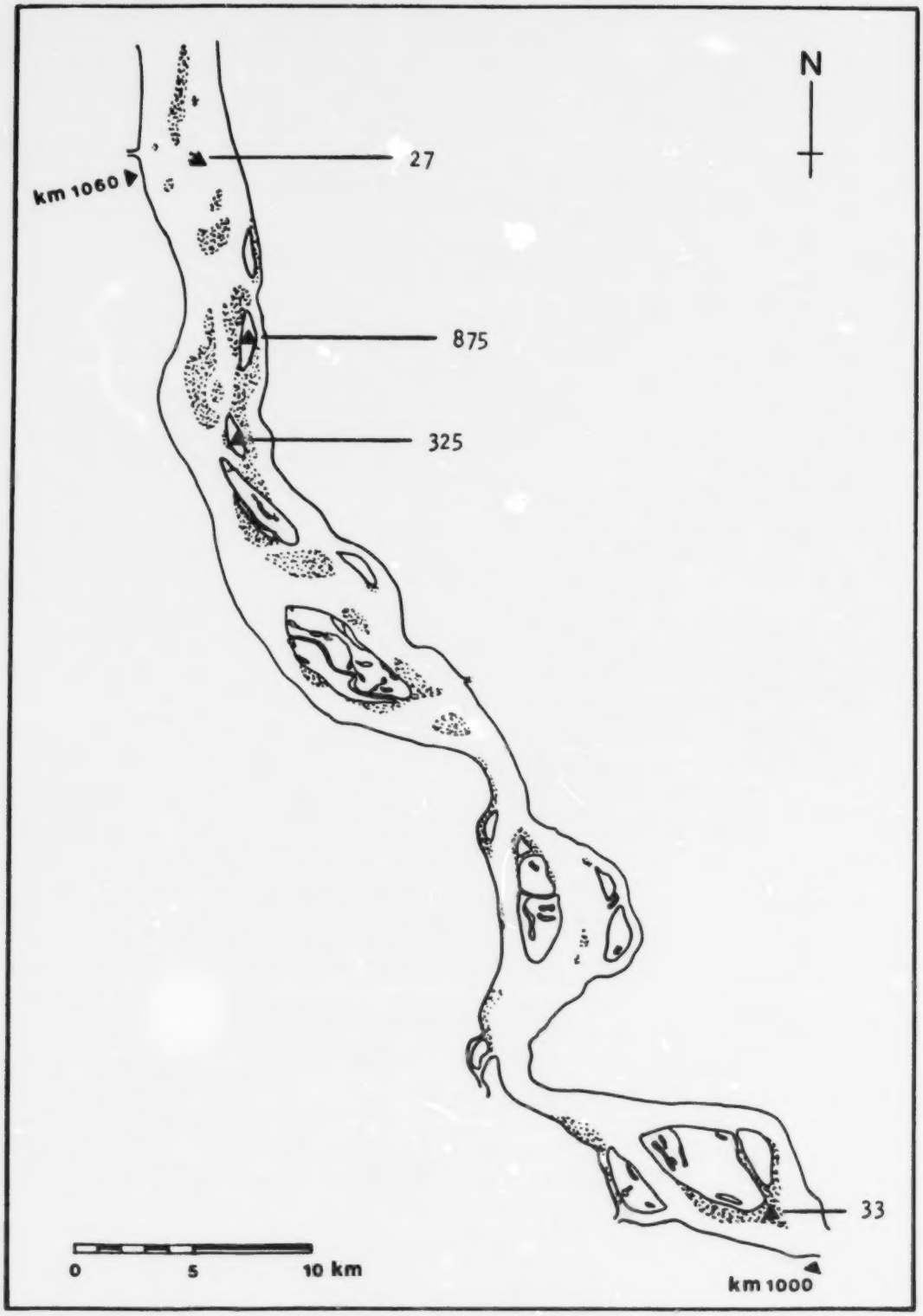
Appendix XIV(c)(cont'd)



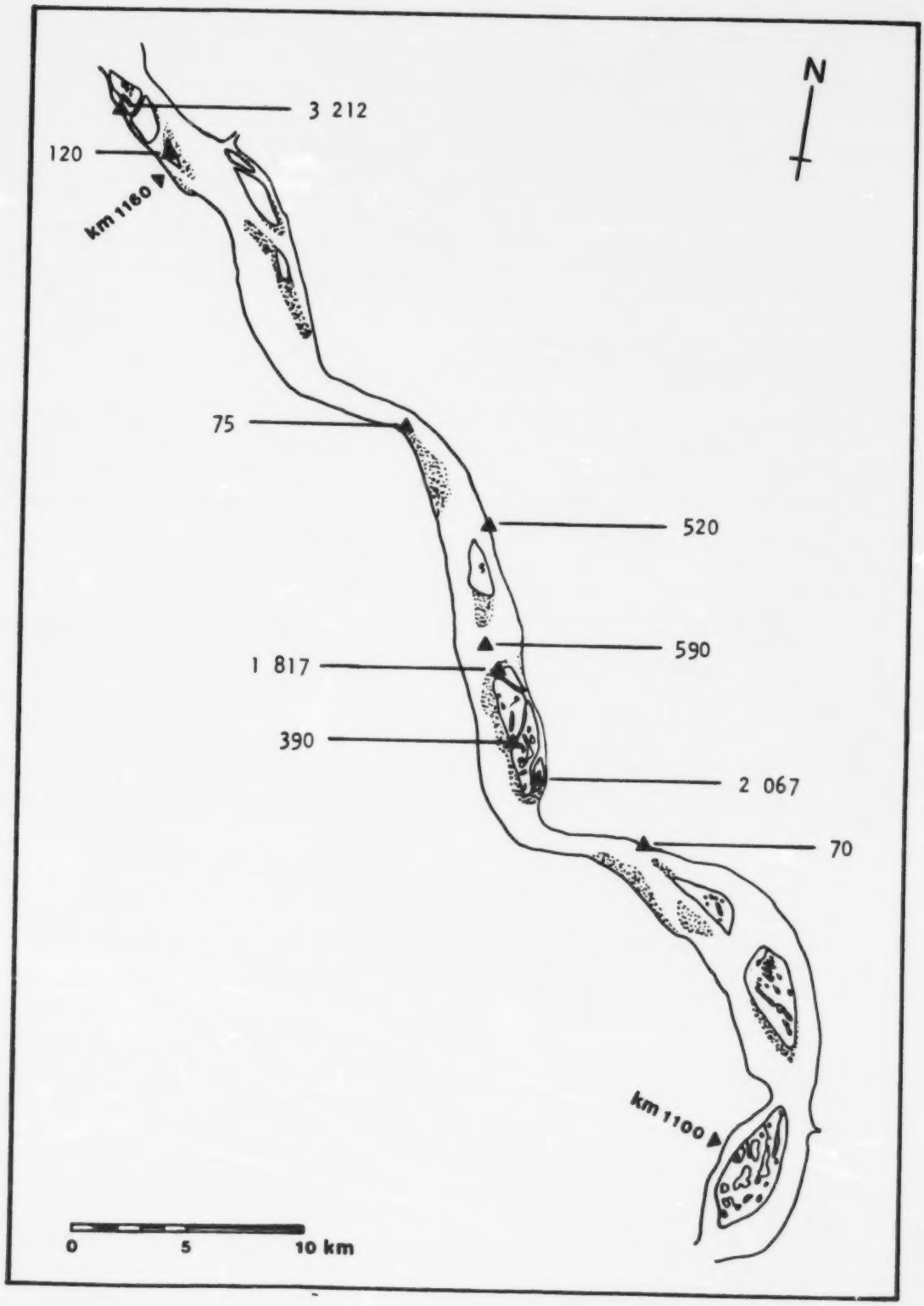
Appendix XIV(d) May 25



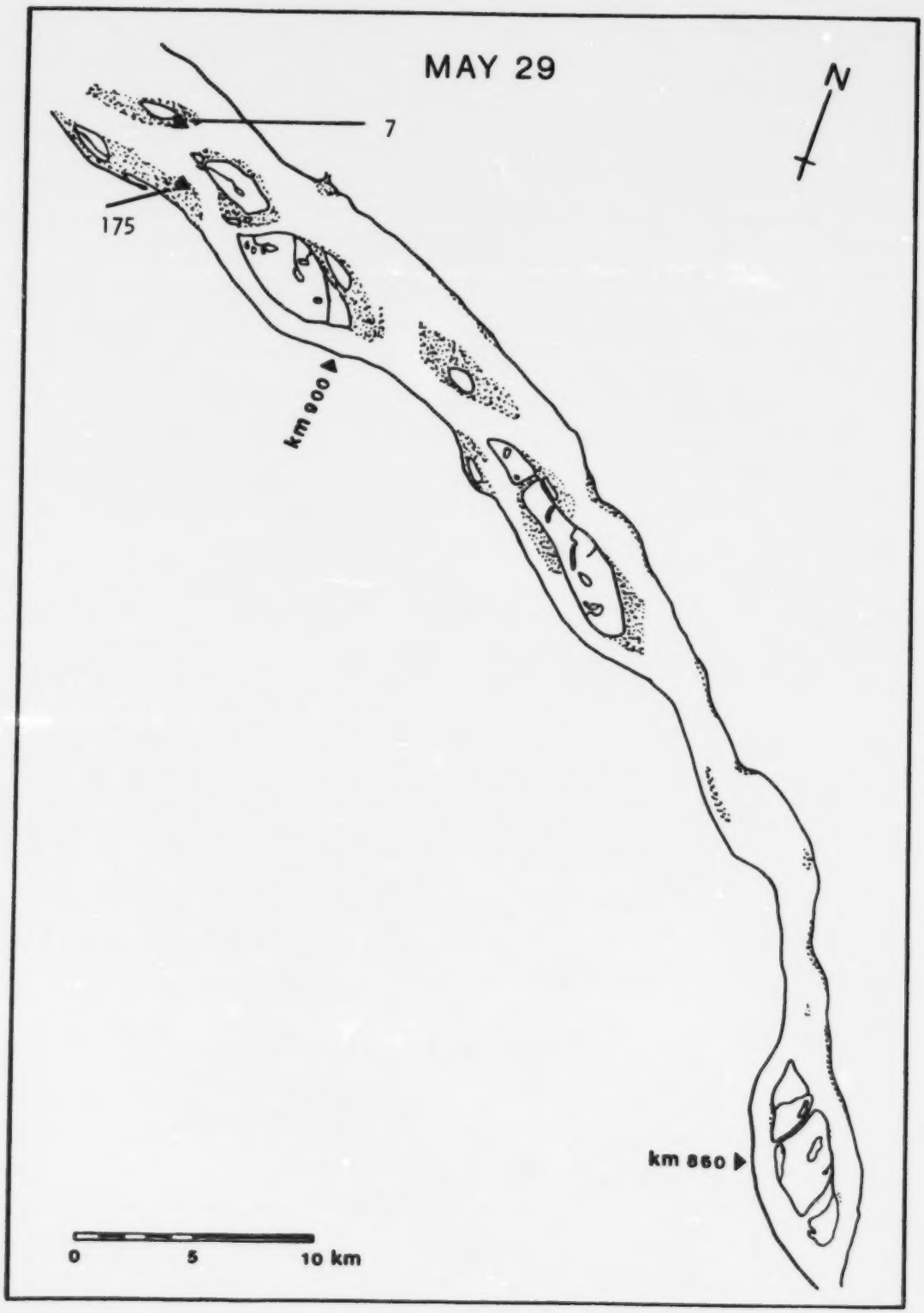
Appendix XIV(d) (cont'd)



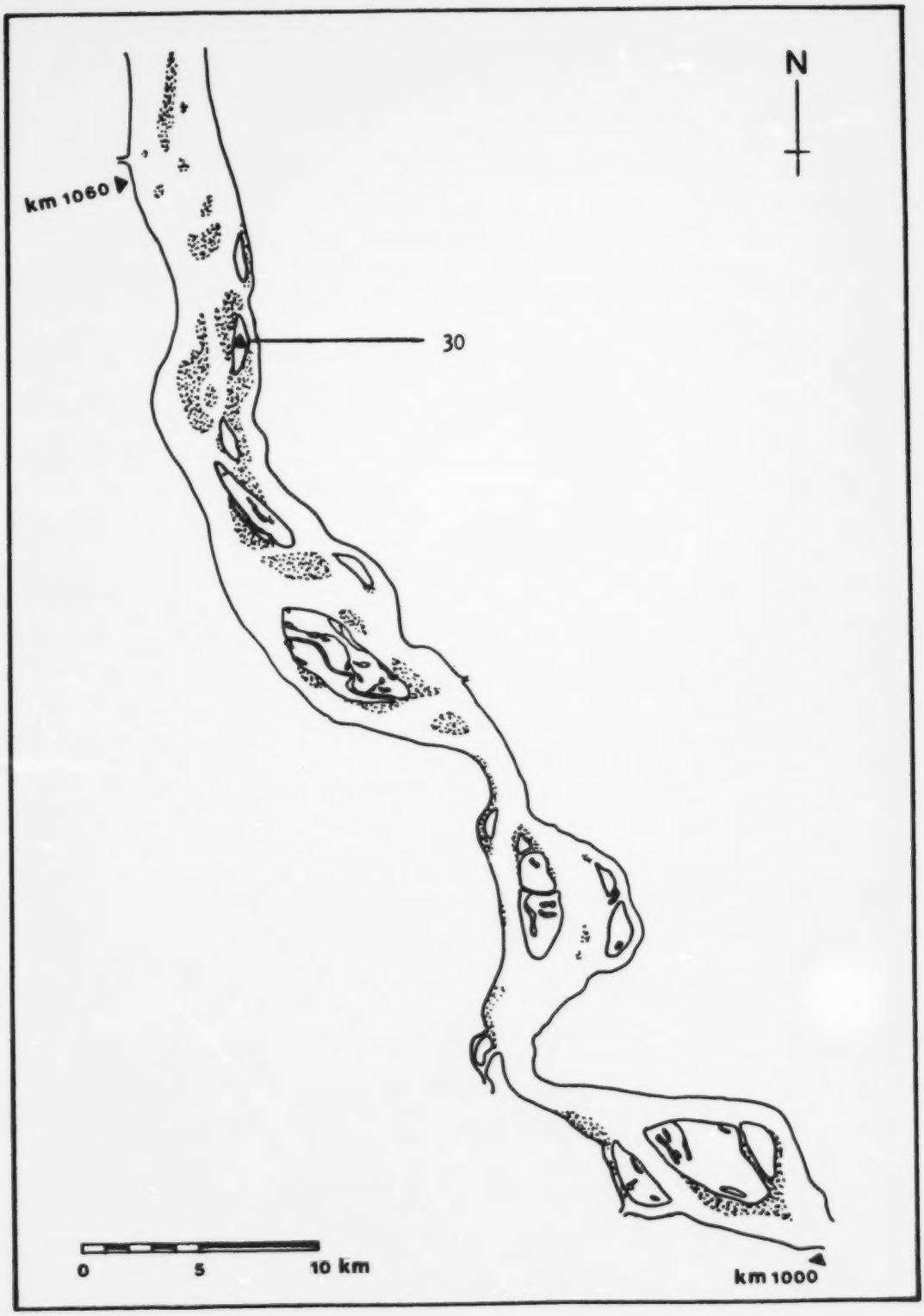
Appendix XIV(d) (cont'd)



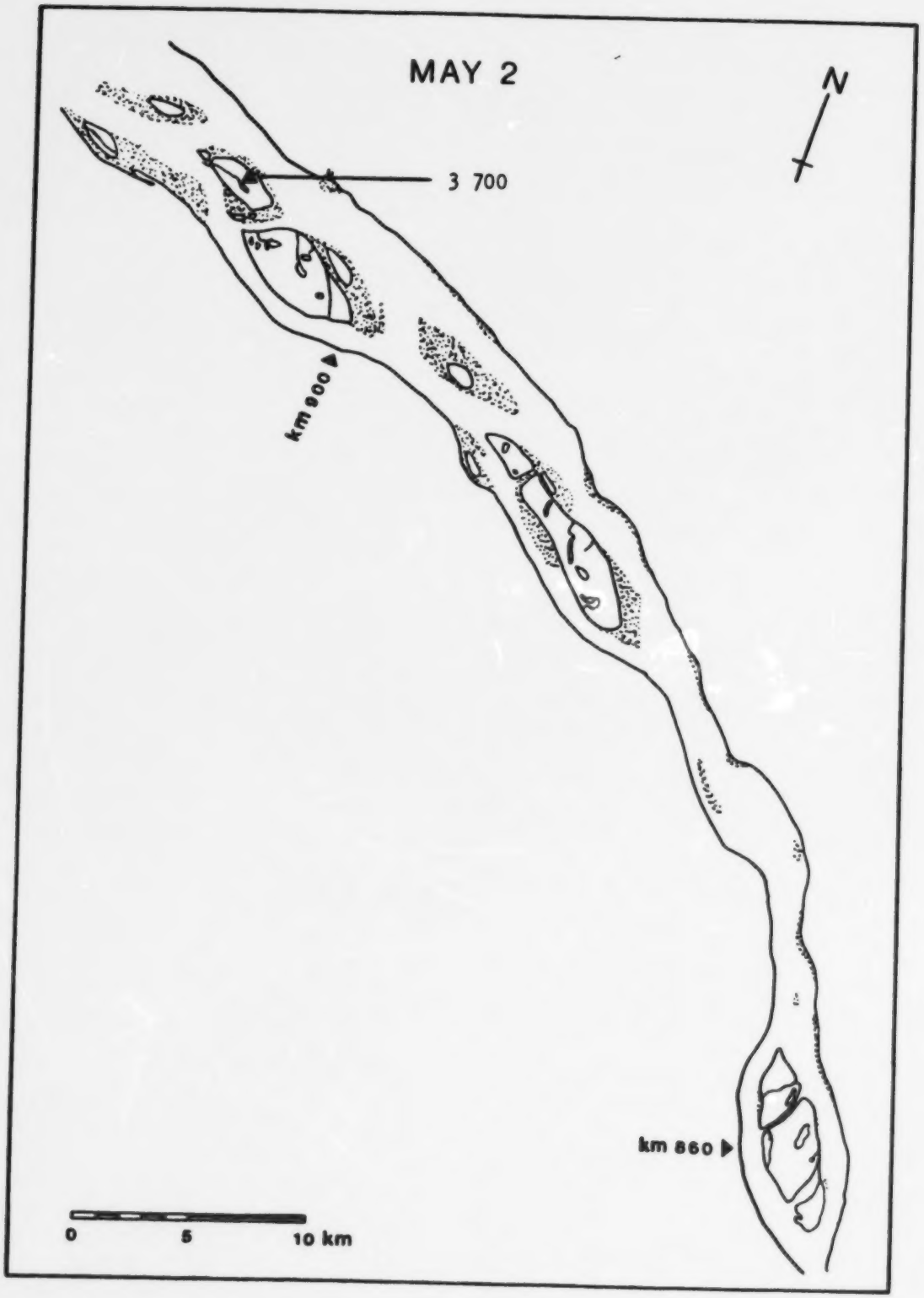
Appendix XIV(d) (cont'd)



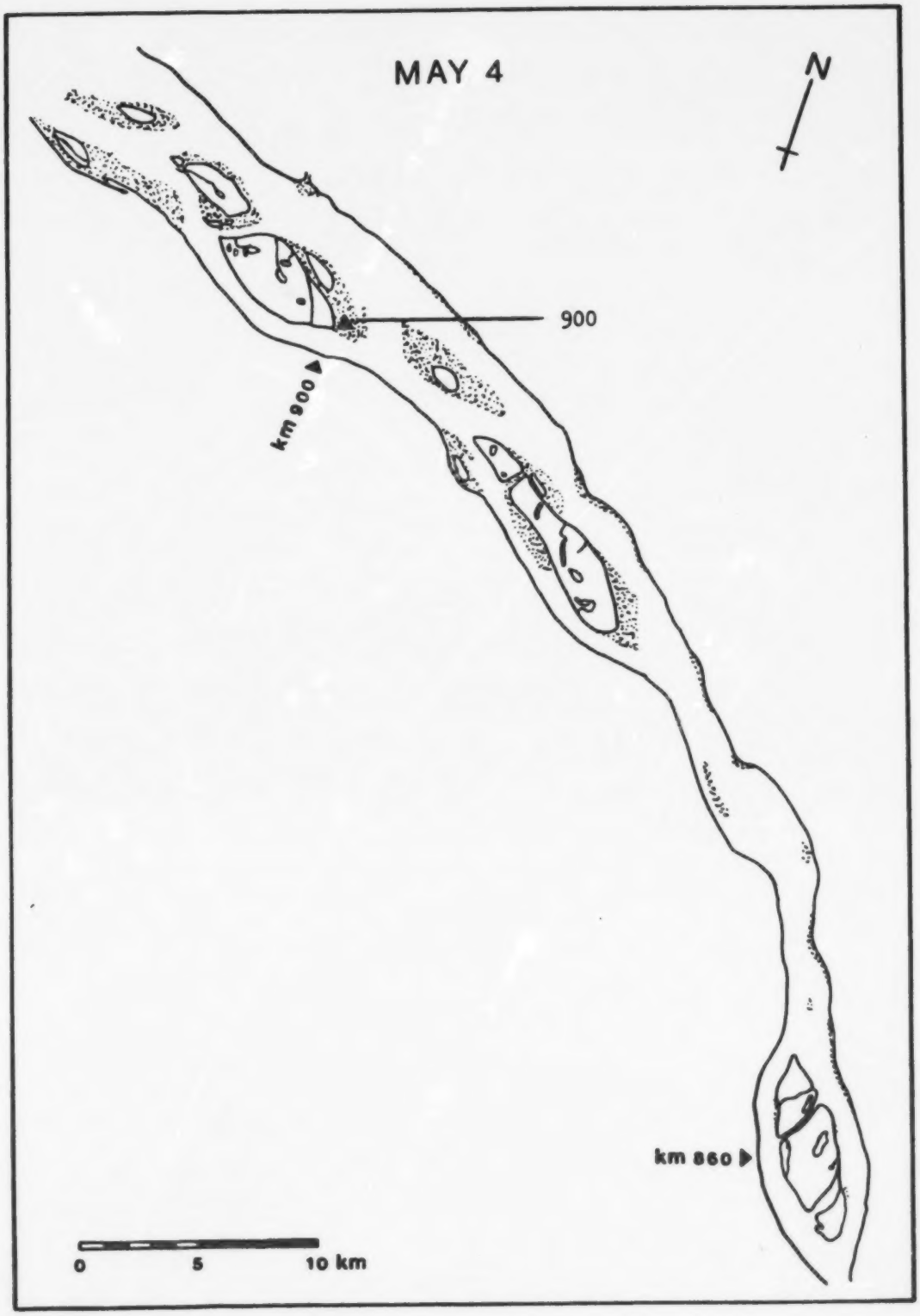
Appendix XIV(e) May 29



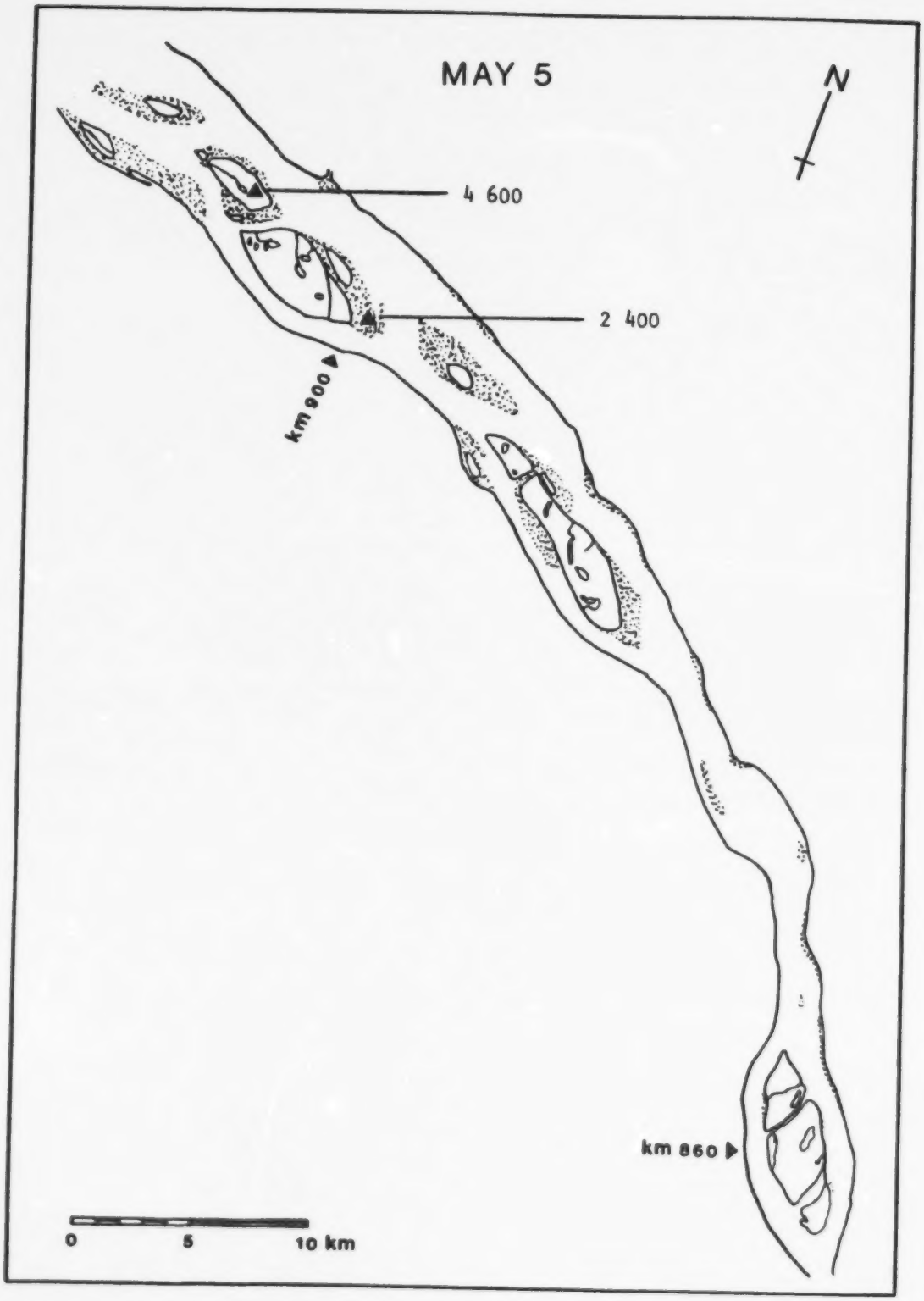
Appendix XIV(e)(cont'd)



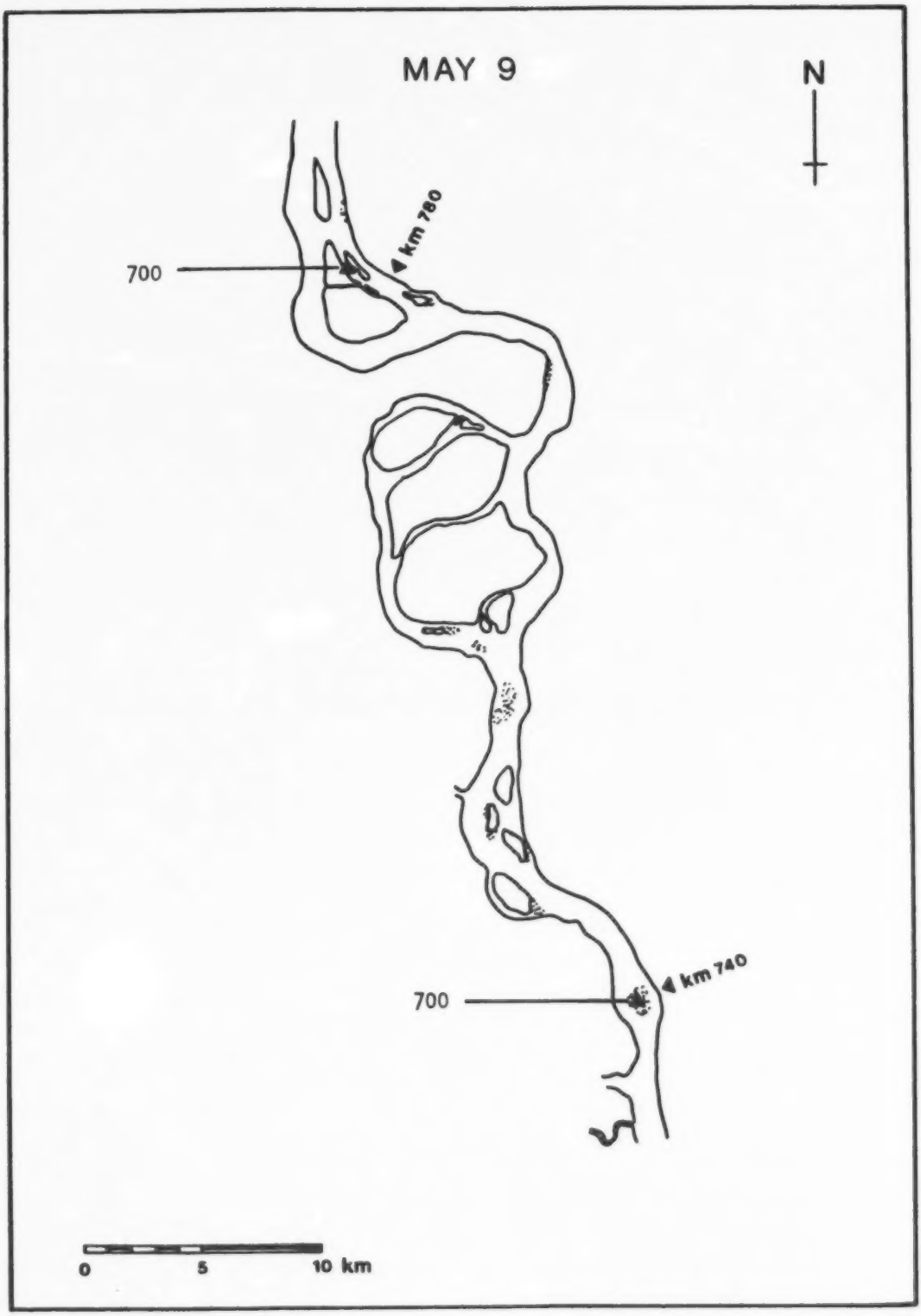
Appendix XV: Locations of snow goose sightings in 1980.
(a) May 2



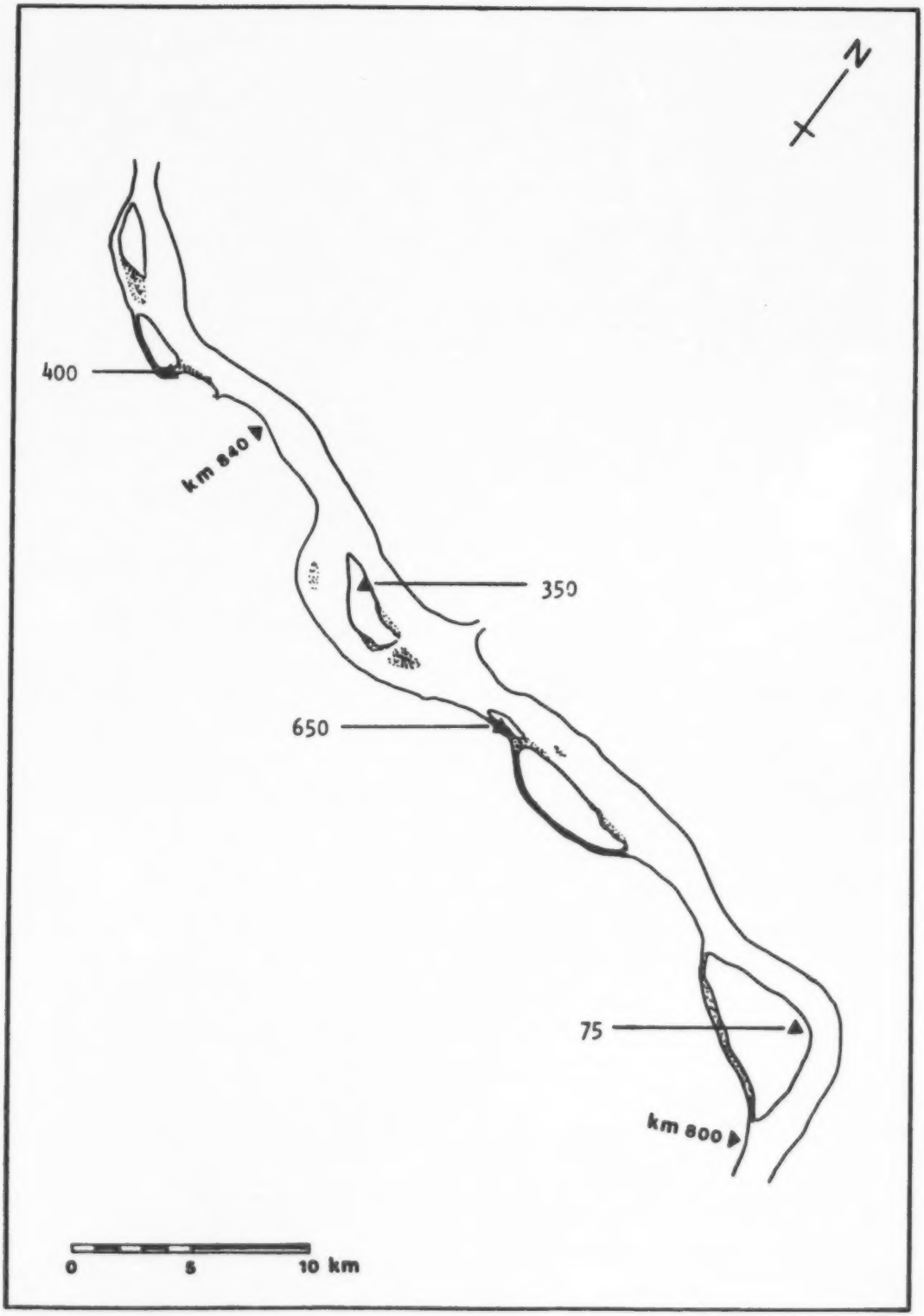
Appendix XV(b) May 4



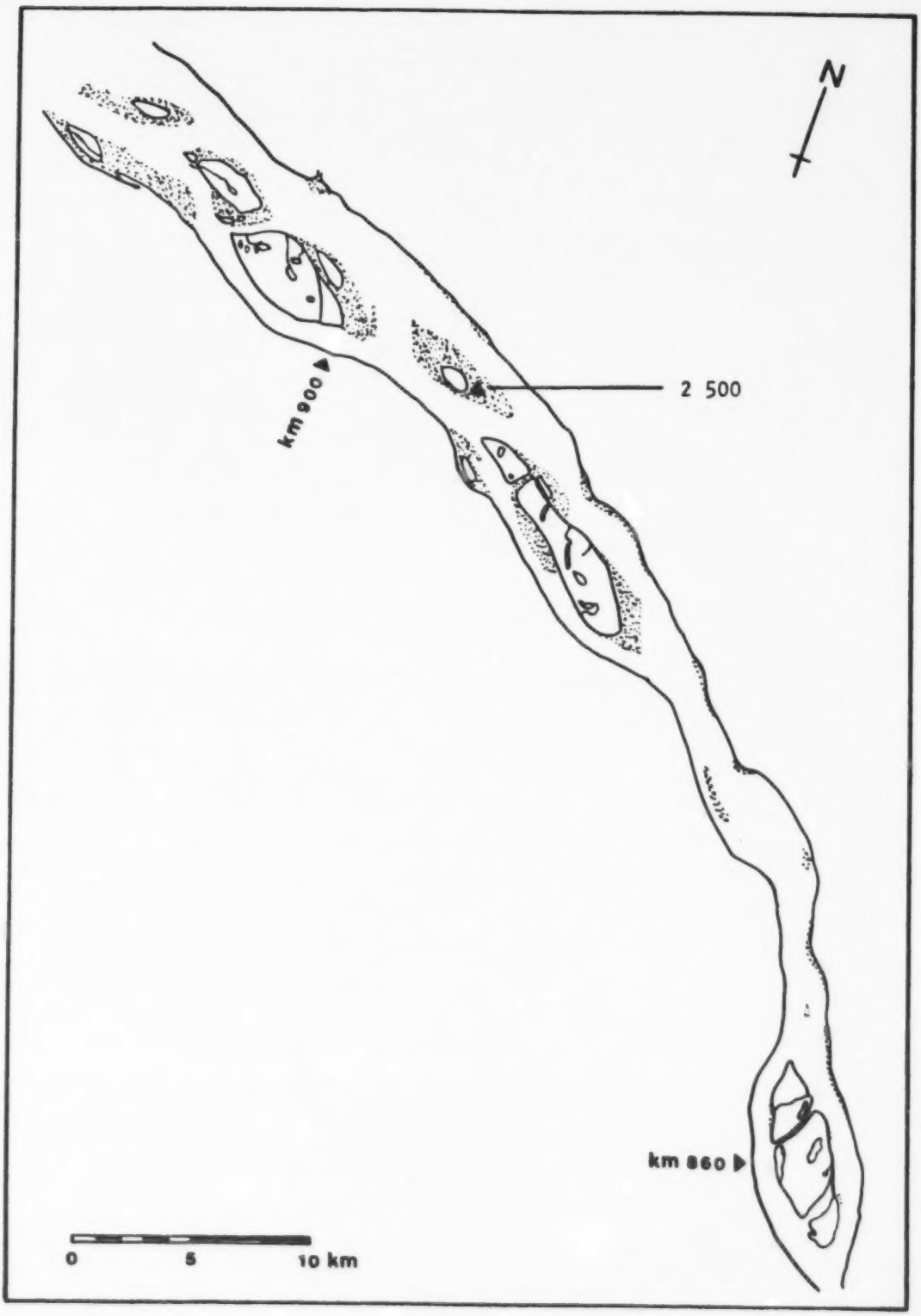
Appendix XV(c) May 5



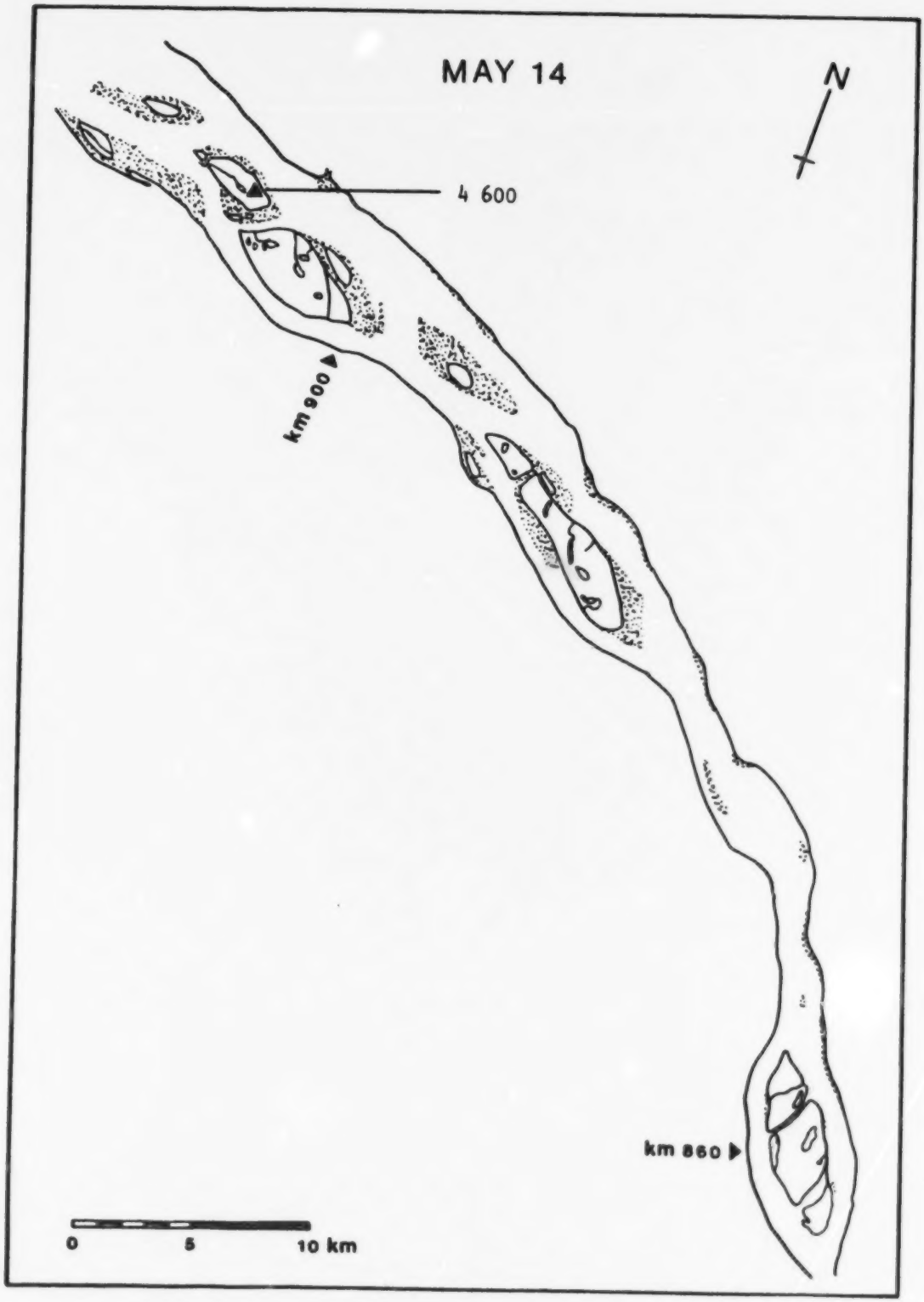
Appendix XV(d) May 9



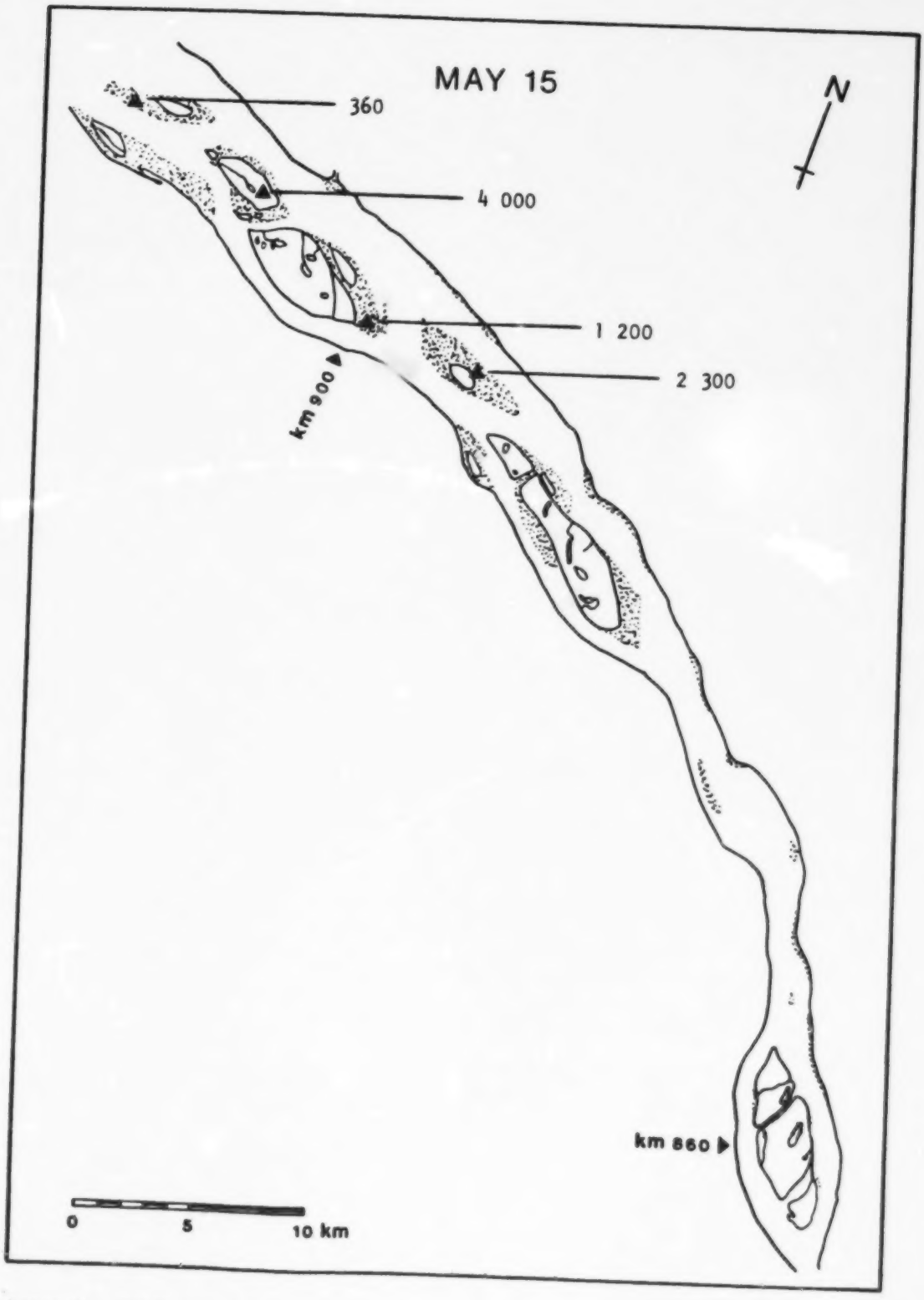
Appendix XV(d) (cont'd)



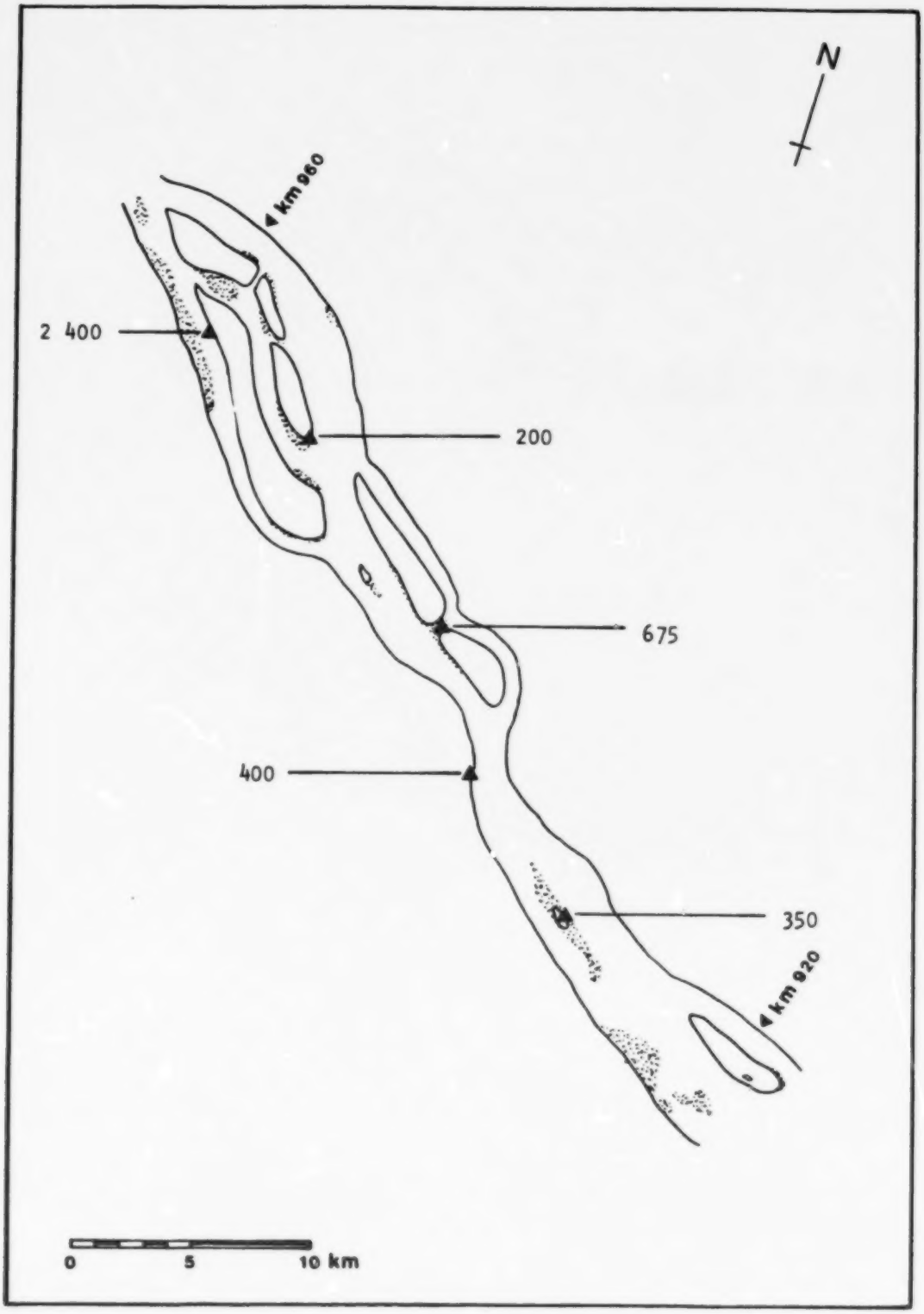
Appendix XV(d) (cont'd)



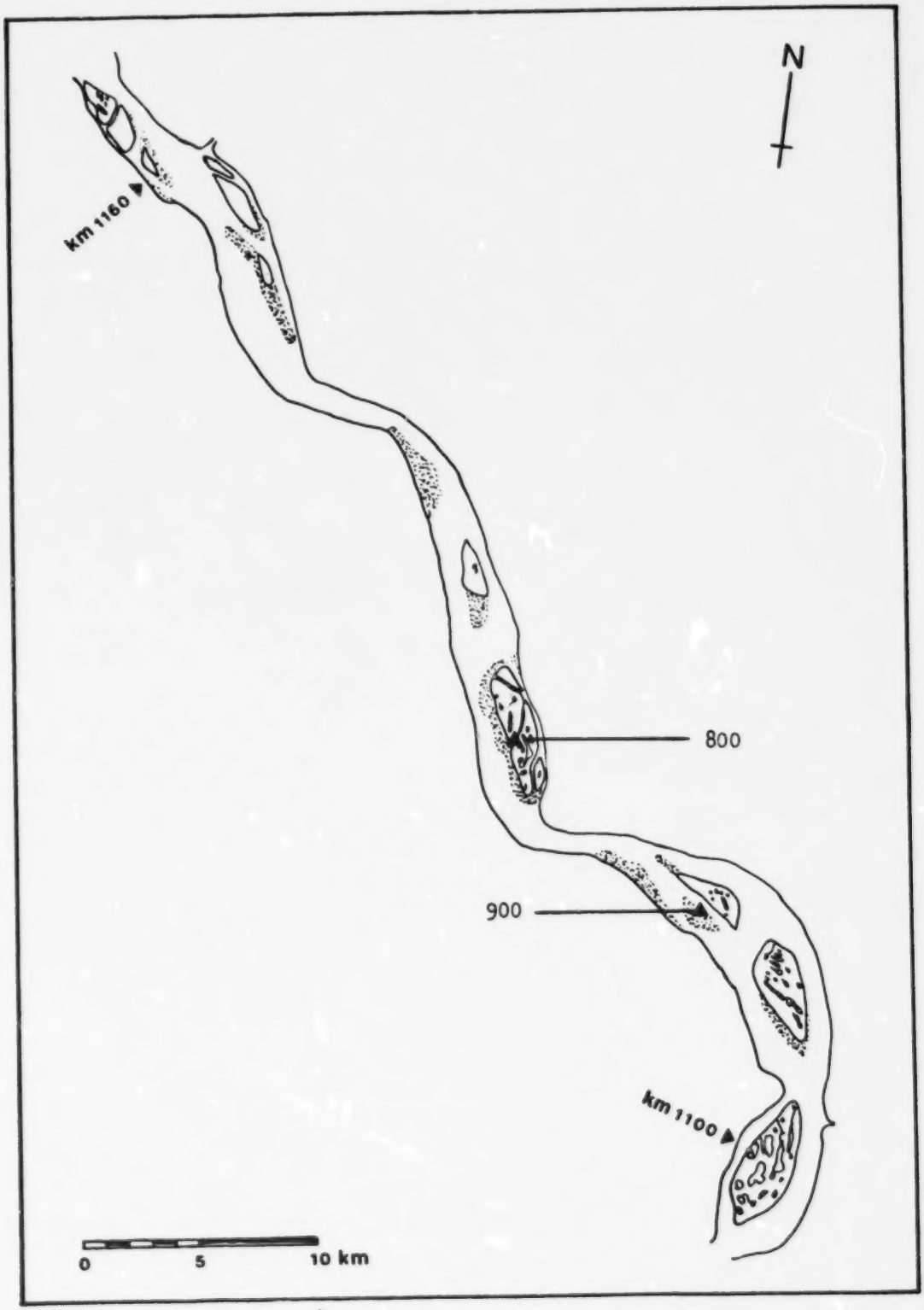
Appendix XV(e) May 14



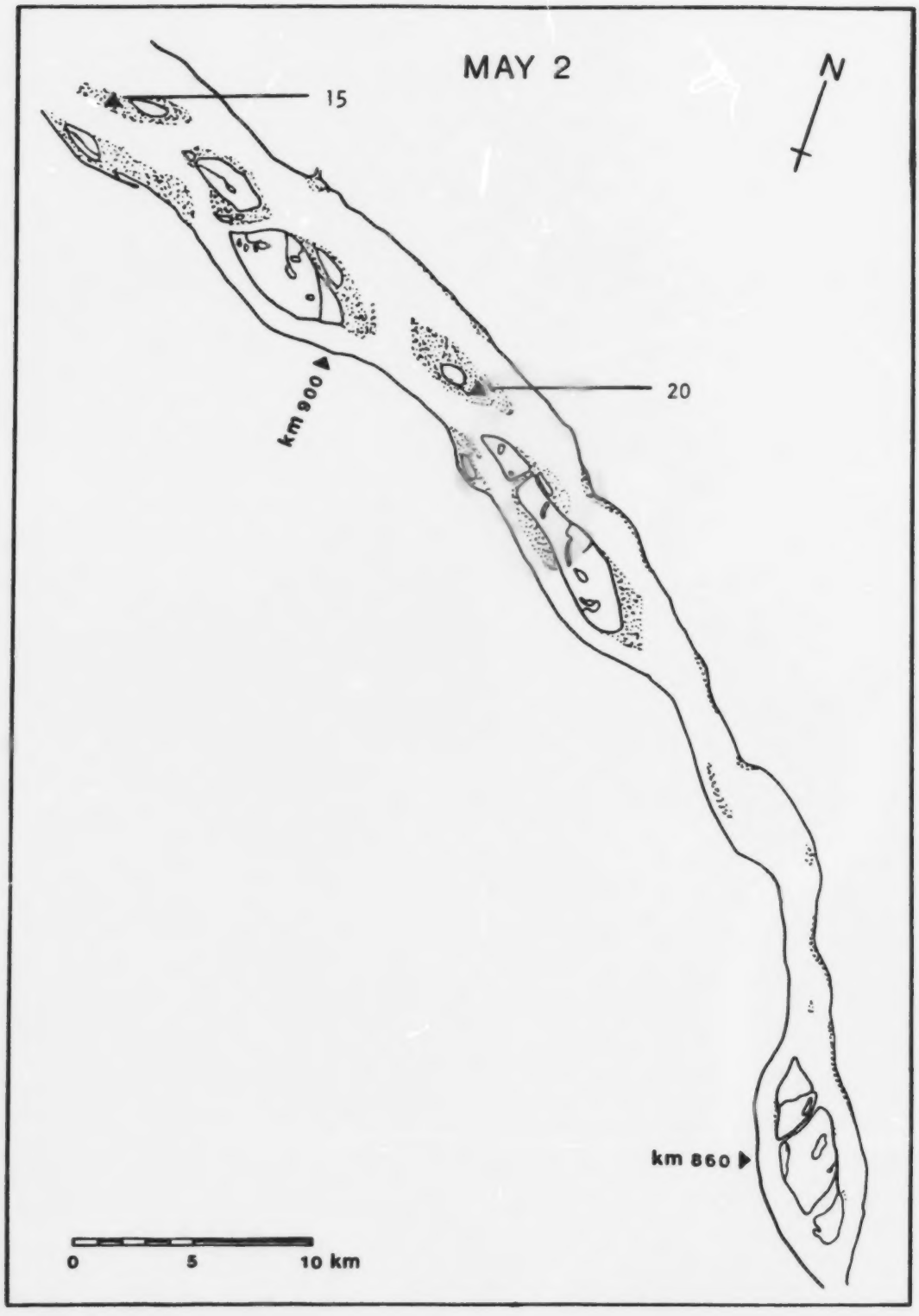
Appendix XV(f) May 15



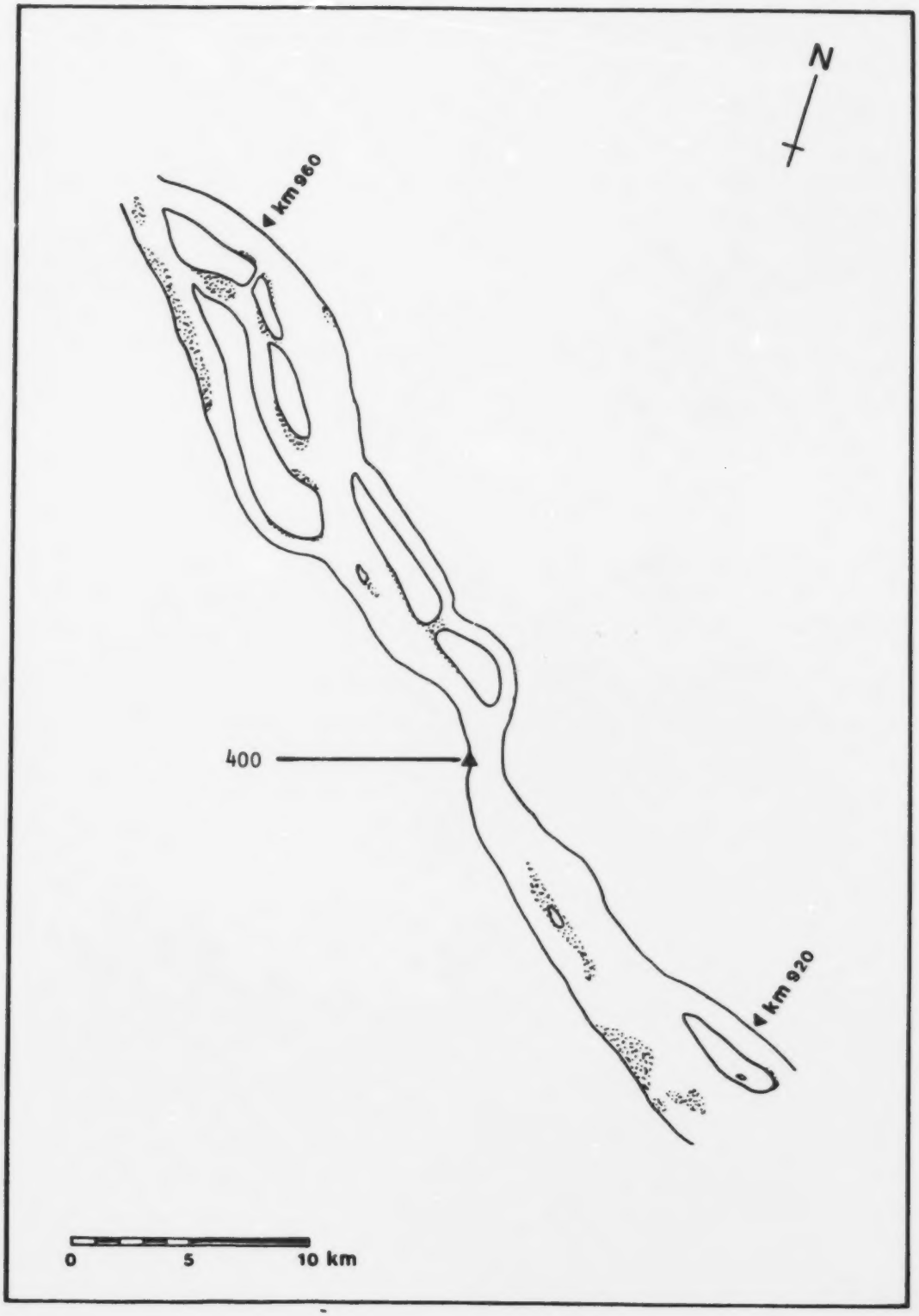
Appendix XV(f)(cont'd)



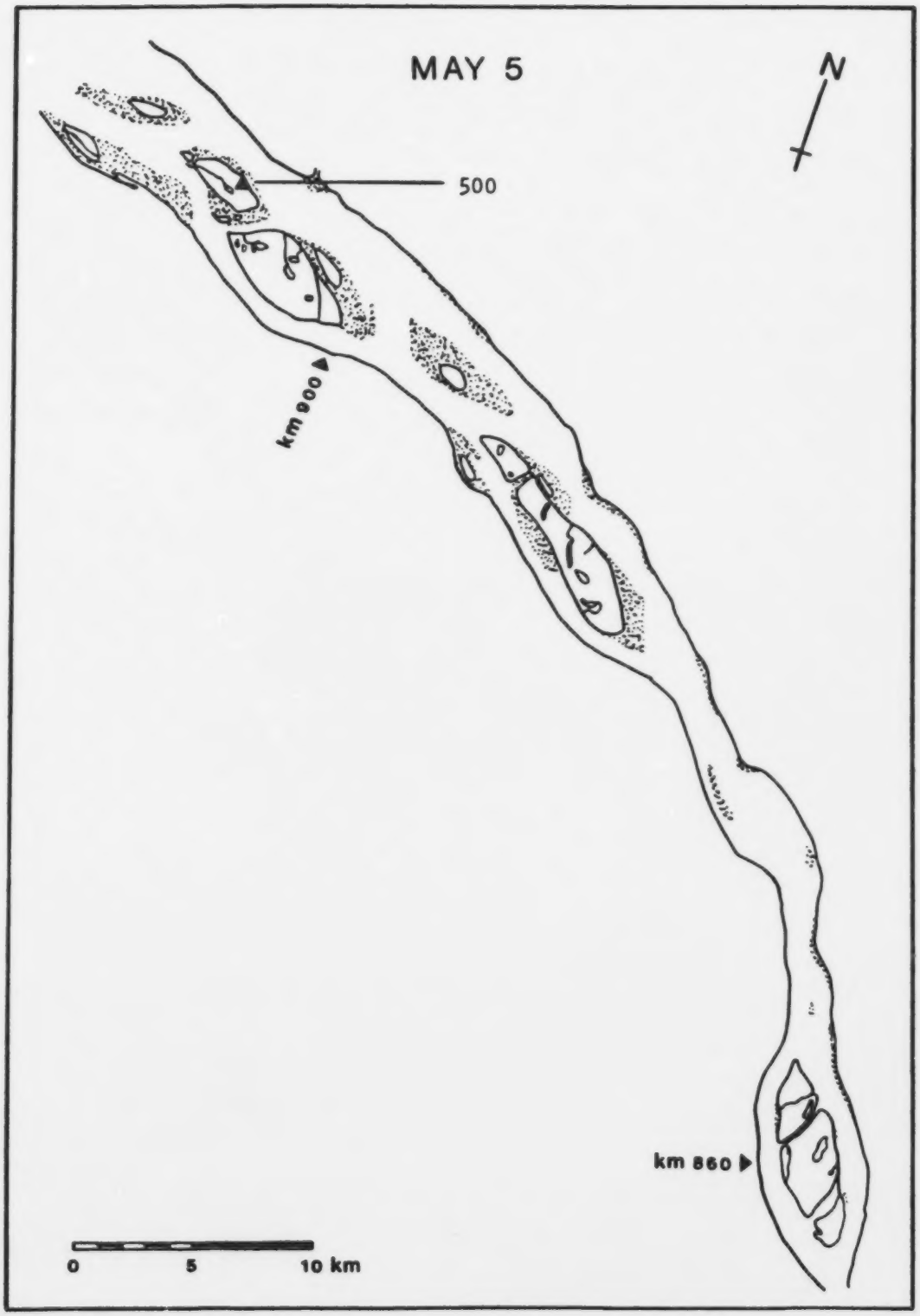
Appendix XV(f)(cont'd)



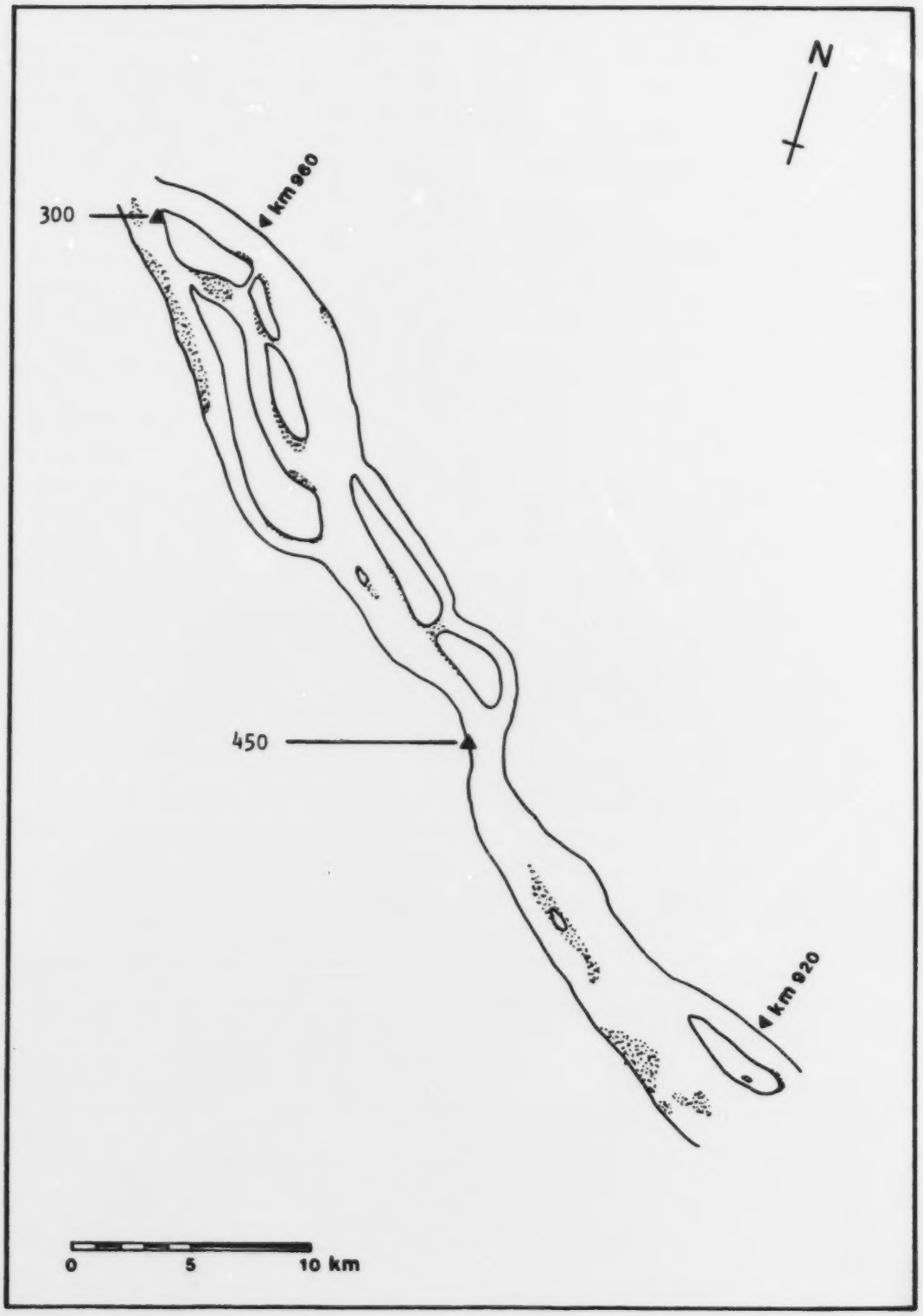
Appendix XVI: Locations of snow goose sightings in 1981.
(a) May 2



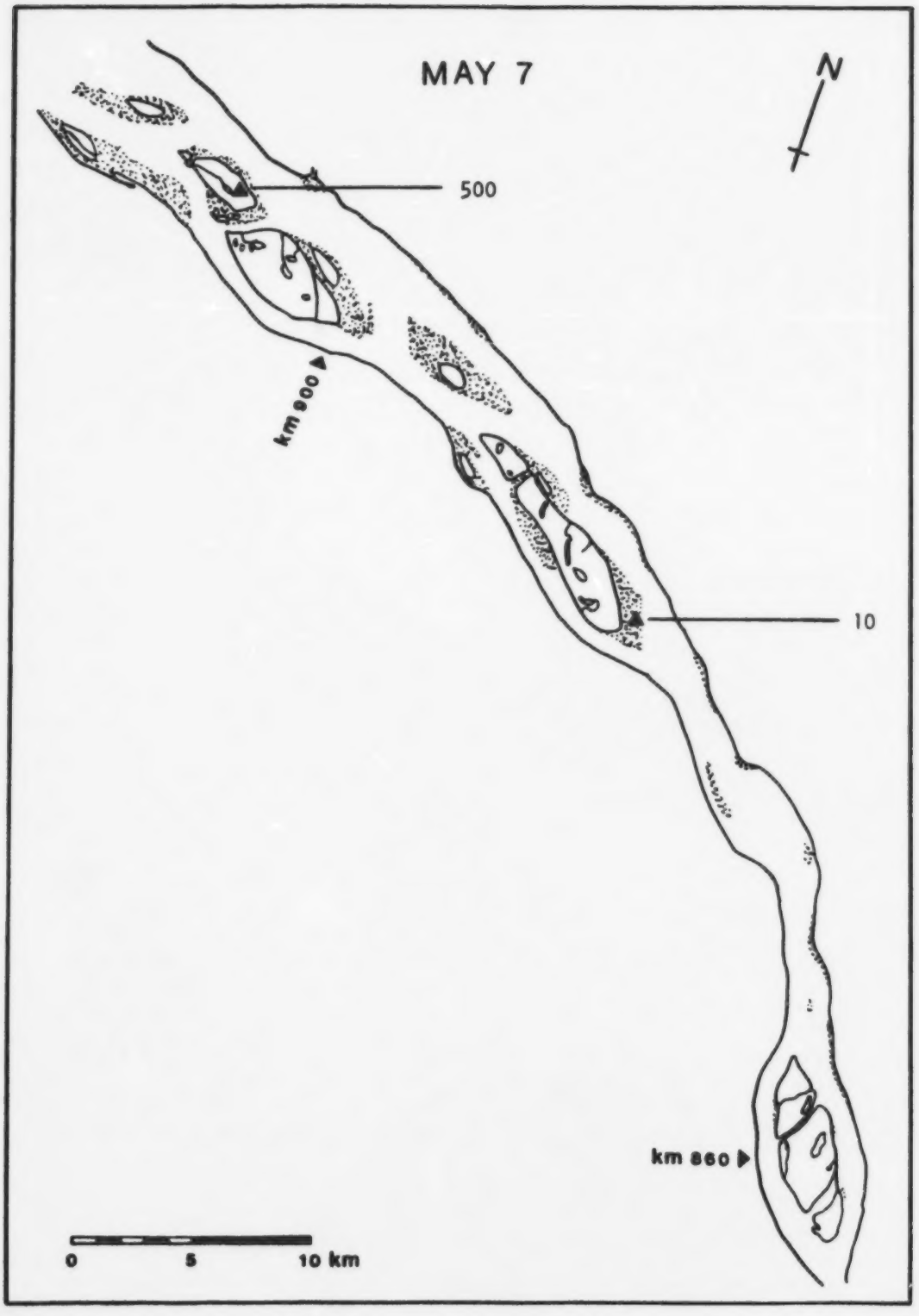
Appendix XVI (a) (cont'd)



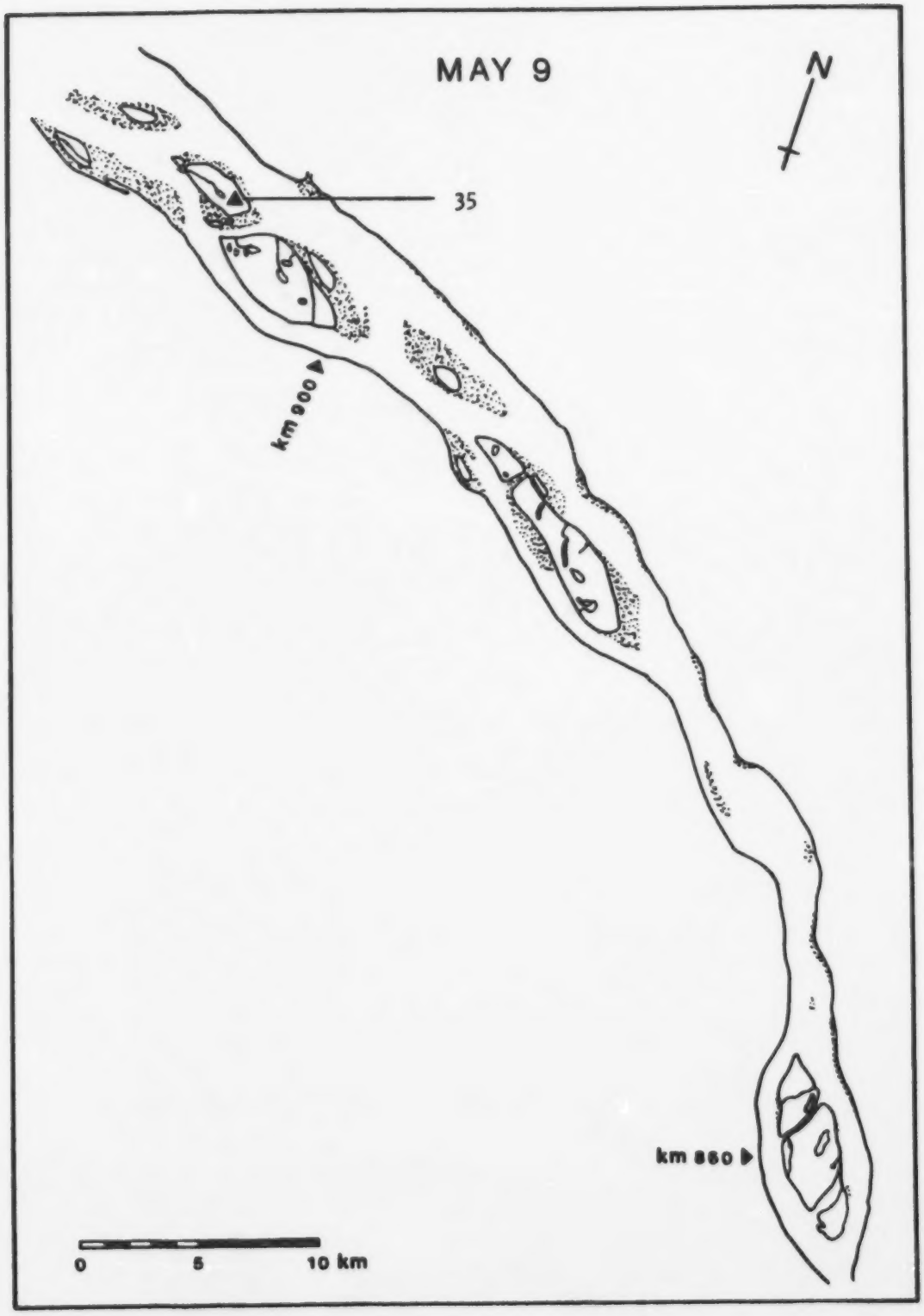
Appendix XVI(b) May 5



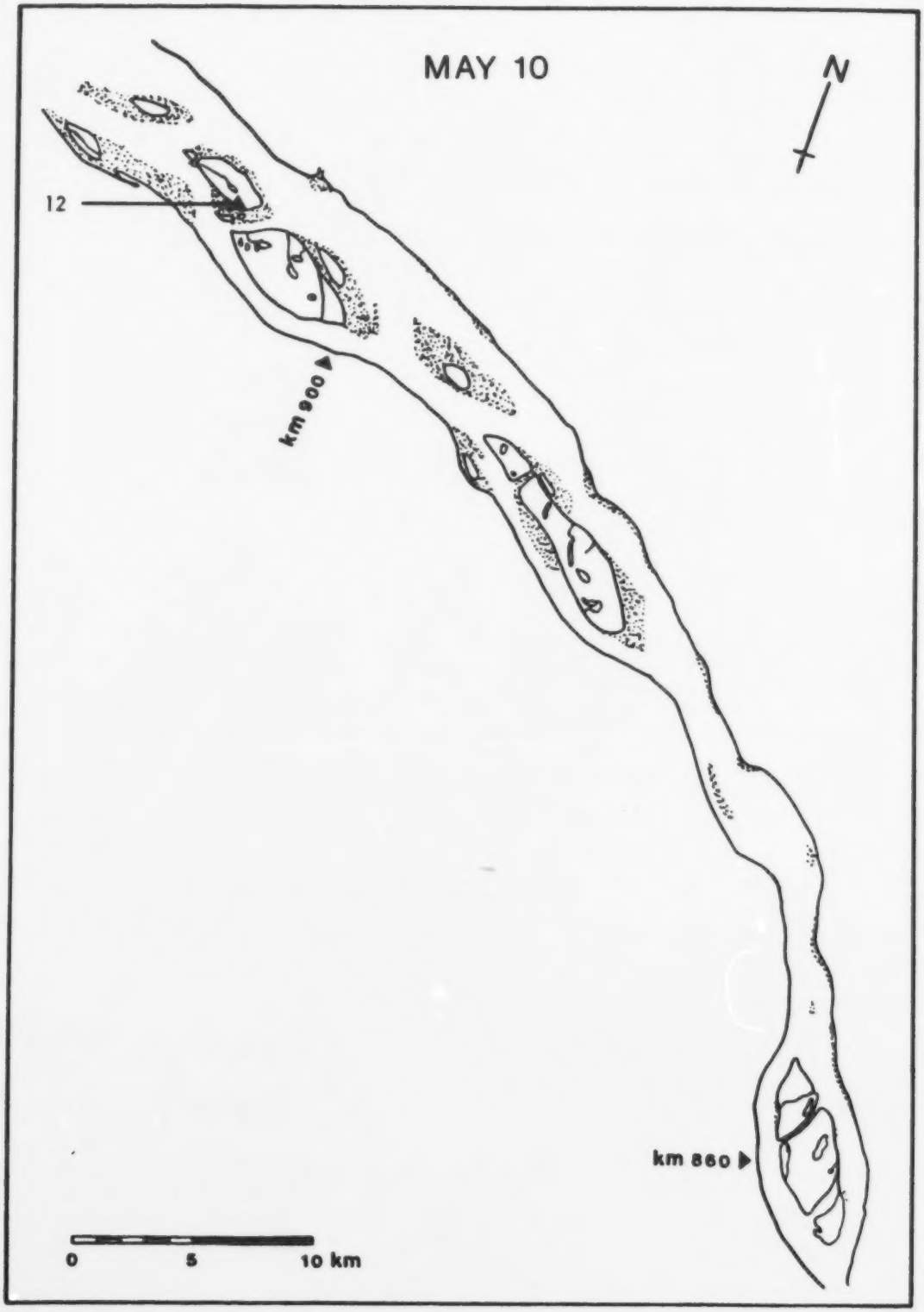
Appendix XVI (b) (cont'd)



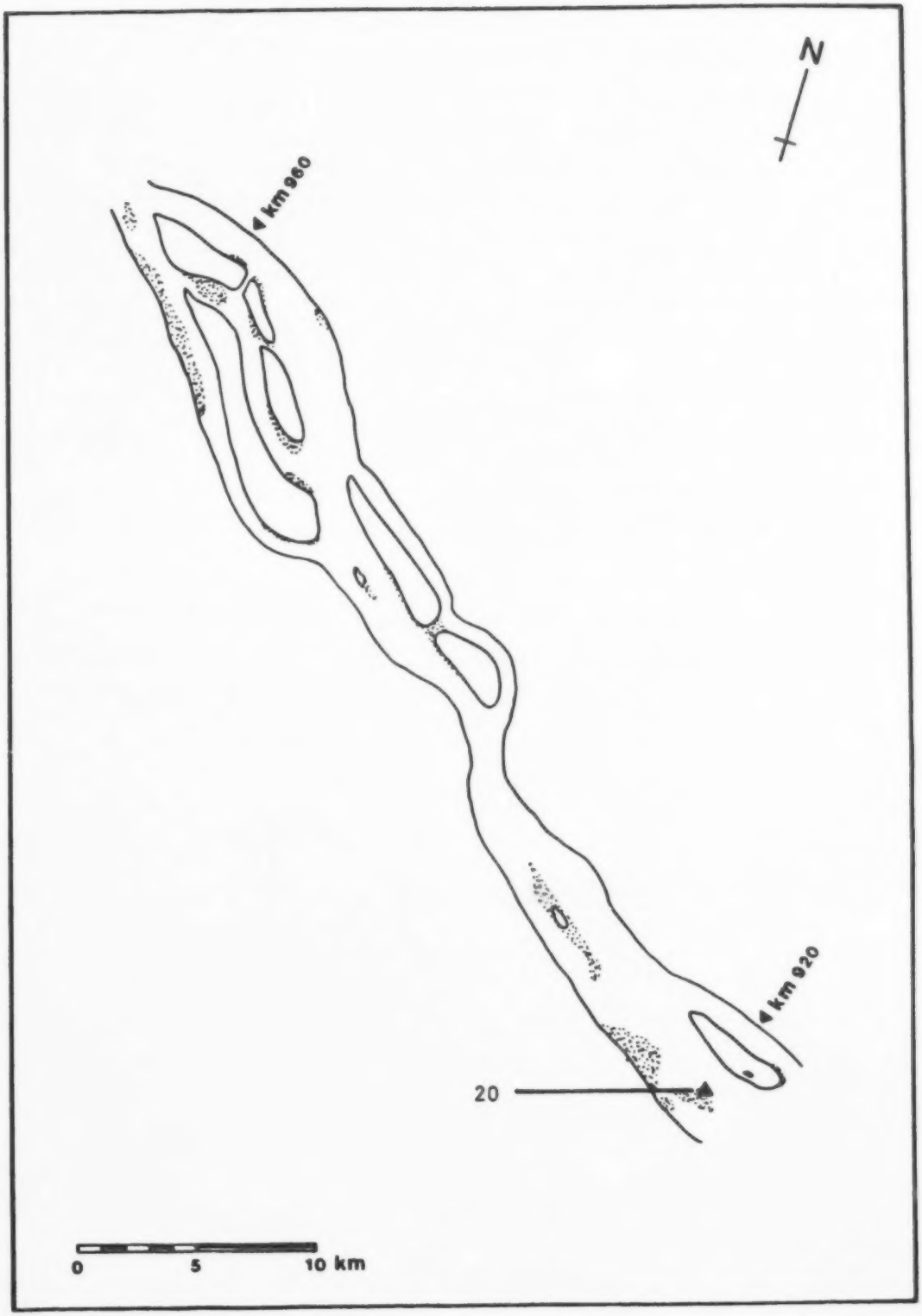
Appendix XVI (c) May 7



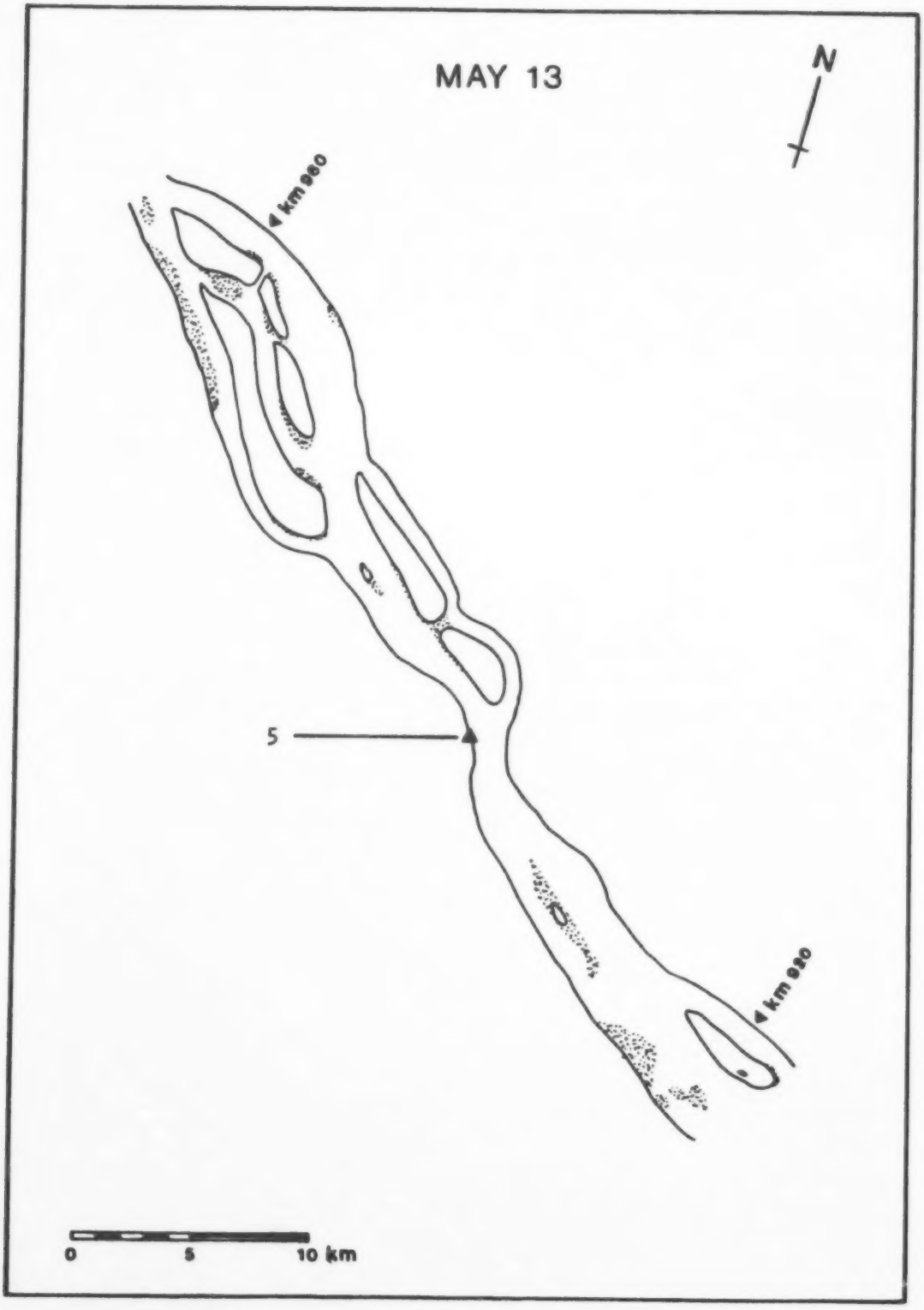
Appendix XVI(d) May 9



Appendix XVI(e) May 10



Appendix XVI (e) (cont'd)



Appendix XVI(f) May 13

Appendix XVII. Listing of snow goose observations made in spring 1980.

Date	Location	Numbers	Comments
April 4	E of Tern L., Alta.	several thousand	moving through in large flocks. Arrived end of March, left 2nd week of April
7,8	Freezeout L., Mont.	70 000 (white geese)	large flocks departed; heading north
14,15	S of Red Deer, Alta.	approx. 200	aerial survey
15	Gleichen, Alta. area	thousands	feeding in fields and on lakes
16	Kerrobert-Kindersley, Sask. area	40 000	
18	Hanna, Alta. area	approx. 500	aerial observations
24	N of Veteran, Alta.	20	all that has been seen
25	Fort Chipewyan, Alta.	50	in flight
27	L. Newell, Alta.	8	
28	Fort Chipewyan, Alta.	10 000	
28	Kindersley-North Battleford, Sask. area		geese moved out 10 days ago
May 1	SE of Barrhead, Alta.	25	
2	Fort Chipewyan, Alta.	125	two flocks (75 and 50)
2	Norman Wells, N.W.T. area[a/]	9 200[b/]	already on river islands
3	Dowling L., Alta.	30	
4	Keele R.-Seagull Is., N.W.T.[a/]	10 600[b/]	
4	Norman Wells, N.W.T. area[a/]	6 400[b/]	
5	Norman Wells, N.W.T. area[a/]	7 000[b/]	
5	Hanna, Alta.	110	all geese field-feeding
6	Beaverhill L., Alta.	1 600 (white geese)	could be Ross' geese
7	Fort Chipewyan, Alta.		geese already departed
8,9	mouth of Rocher R., N.W.T.	thousands	moving through steadily
9	Oakland L., Alta.	approx[b/] 30	
9	Keele R.-Seagull Is., N.W.T.[a/]	11 400[b/]	
9	Norman Wells, N.W.T. area[a/]	12 700[b/]	

Appendix XVII (cont'd)

Date	Location	Numbers	Comments
12	Fort Simpson, N.W.T.		Mackenzie R. open since April 29; free of ice May 3; no geese seen
14	Keele R.-Seagull Is., N.W.T.	none b/	
15	Norman Wells, N.W.T. area a/	10 260 b/	river not open yet; geese moving through steadily
15	Fort Good Hope, N.W.T.	5 400 b/	
19	Norman Wells, N.W.T. area a/	none b/	

a/ Ten Mile Island - Mac Island

Sources: Environmental Management Associates (1980) except for data marked " b/ "

b/ R. Webb Environmental Services Ltd. (1980)

Appendix XVIII. Listing of snow goose observations made in spring 1981.

Date	Location	Numbers	Comments
March 22,23	Freezeout, L., Mont.	80 000-100 000	moved on
28,29	Kindersley, Sask.	a few	
28	Hanna, Alta.	50-60	in flight over slough
		approx. 200	south of Hanna
April 3-10	Kindersley, Sask.	a few	
	Coleville, Sask.	a few	
4	Beaverhill L., Alta.	1	
5	Beaverhill L., Alta.	3	
8	Beaverhill L., Alta.	none	
9	Provost, Alta	few	just arrived
9	Fort Chipewyan, Alta.	3-4	
10	Shallow L., Sask.	approx. 20 000	a wild guess
11	Moose Jaw, Sask.	3	flying west
14	Smiley, Sask.	20+	
15	Milk River, Alta.	approx. 1 200	
16	Luseland, Sask.	thousands	feeding in stubble fields
19	Fort Simpson, N.W.T.	1	
20-22	Grande Prairie, Alta.	a few	
20	Peace River Alta.	some	seen in a field
20	Provost, Alta.	fewer than before	
21	Slave Lake, Alta.	some	in flight over Slave L.
21,22	Teo L., Sask.	some	
22	Alsask, Sask.	20+	
22	Kindersley, Sask.	1 000-1 200	observed NW of Kindersley; no sign of movements
23	Cutbank L., Sask.	190	130 in flight
24	Dewar L., Sask.	250	in flight
	Buffalo Coulee, Sask.	8 700-10 000	
	Kerrobert, Sask.	350	
	Shallow L., Sask.	1 000	
	Cactus L., Sask.	1 600	1 000 in a slough nearby
24	Peace-Athabasca Delta, Alta.	isolated flocks, 200-300 in total	flocks of 20-25 birds
24	Norman Wells, N.W.T.	some	
25	Fort Good Hope, N.W.T.	approx. 50	
25	Fort Chipewyan, Alta.	4	

Appendix XVIII (cont'd)

Date	Location	Numbers	Comments
27	Fort Chipewyan, Alta.	some	near mouth of Embarras R.
27	Provost, Alta.	600-800	last observation, moved out
30	Sandy Lake Hill, Alta.	70	
30	Norman Wells, N.W.T	some	heading northward
May 1	Aklavik, N.W.T.	some	observed at Mackenzie Delta
1	Fort Chipewyan, Alta.	150-160	in flight
1	near Hanna, Alta.	3	
2	Norman Wells, N.W.T. area[a/]	435[b/]	
3	Fort Chipewyan, Alta.	3	in flight
5	Fort Simpson, N.W.T.	26	in flight along Mackenzie River
5	Norman Wells, N.W.T. area	1 250[b/]	
6	Peace-Athabasca Delta, Alta.	25 000-30 000	aerial observation
7	Buffalo Coulee, Sask.	200	
7	Slave River, Alta.	50-55	in flight
7	Norman Wells, N.W.T. area	525[b/]	
8	Fort Chipewyan, Alta.	25 000	
9	Norman Wells, N.W.T. area	35[b/]	
10	Viking, Alta.	64	flying north
11	Vermilion, Alta.	150	
12	Norman Wells, N.W.T. area	5 000-6 000[b/]	movement of 100 birds/ 15 min; one group of 2 000 heading SE
14	Czar, Alta.	150	

[a/] Ten Mile Island - Patricia Island

Sources: Environmental Management Associates (1982) except for data marked " b/ "

[b/] R. Webb Environmental Services Ltd. (1983)

Appendix XIX. Listing of snow goose observations made in spring 1983.

Date	Location	Numbers	Comments
March 26	Freeze-out L., Mont.		large movement
April 1	Freeze-out L., Mont.		large movement
5	Unity, Sask.	several hundred	
10	Hanna, Alta.	50	
14	Shooting L., Alta.	<50	
15	Matioli L., Alta.	4 000	
18	Luseland, Sask.	lots	
18	Matioli L., Alta.	500	
19	Fort Simpson, N.W.T.	<100	small flocks
21	Wood Buffalo Nat'l Park, Alta.	not many	
21	Lethbridge, Alta.	830	on lakes in the area
21	Macklin, Sask.	lots	
25	Swift Current, Sask.		flights now going through
25	Rosetown, Sask.	few	
27	Peace R., Alta.	3 000	
27	Hayter, Alta.	lots	
May 3	Radisson, Sask.	2 000-3 000	
3	Fort Chipewyan, Alta.	2 500	
4	Norman Wells, N.W.T.	2	
4	Fort Simpson, N.W.T.		larger numbers
5	Meadow Lake, Sask.	thousands	
5	Opuntia L., Sask.	1 500	
6	Fort Simpson, N.W.T.	several hundred	
7	Macklin, Sask.	75	
8	Norman Wells, N.W.T. area[a/]	205[c/]	
9	Meadow Lake, Sask.	none	
10	Norman Wells, N.W.T. area	827[d/]	
12	Norman Wells, N.W.T. area	2 022[c/]	
13	Norman Wells, N.W.T. area	2 336[c/]	
13	Norman Wells, N.W.T. area	7 219[c/]	
17	Fort Good Hope, N.W.T. area[b/]	853[c/]	
18	Norman Wells, N.W.T. area	27 778[c/]	
18	Fort Good Hope, N.W.T. area	2 315[c/]	
23	Norman Wells, N.W.T. area	22 286[c/]	
23	Fort Good Hope, N.W.T. area	18 930[c/]	
24	Norman Wells, N.W.T. area	9 861[c/]	

Appendix XIX (cont'd)

Date	Location	Numbers	Comments
24	Fort Good Hope, N.W.T. area	18,214[c/]	
29	Norman Wells, N.W.T. area	2[c/]	
29	Fort Good Hope, N.W.T. area	none[c/]	

a/ Ten Mile Island - Patricia Island

b/ Fort Good Hope - Tieda River

Sources: Environmental Management Associates (1983) except for data marked " c/ " and " d/ "

c/ D. Ealey (pers. comm.)

d/ author

Appendix XX. Listing of snow goose observations made in spring 1984.

Date	Location	Numbers	Comments
April 2	Chin Reservoir, Alta.	1 000	
16	Sounding L., Alta.	2 600	migration earlier
19	Beaverhill L., Alta	some	
24	Fort Chipewyan, Alta.	thousands	first to arrive
29	Redstone R., N.W.T.	1 500	
29	Norman Wells, N.W.T.	400-600[c/]	more overflights than usual
May 1	Norman Wells, N.W.T.	21	still staging
1	Peace R., Alta. area	50±[d/]	flew over town
2	Beaverhill L., Alta.	4 000-6 000[c/]	
3	Paulatuk, N.W.T.	4 578[e/]	
6	Brackett L., N.W.T.	1 100[e/]	
8	Norman Wells, N.W.T. area[a/]	3 115[e/]	
8	Fort Good Hope, N.W.T. area[b/]	770[e/]	
10	Norman Wells, N.W.T. area	2 544[e/]	
10	Fort Good Hope, N.W.T. area	1 700[e/]	
12	Norman Wells, N.W.T. area	1 252[e/]	
12	Fort Good Hope, N.W.T.	1 955[e/]	
15	Norman Wells, N.W.T area	6 107[e/]	
15	Fort Good Hope, N.W.T. area		a lot less
15	Brackett L., N.W.T.		
16	Fort Chipewyan, Alta. area		

a/ Ten Mile Island - Patricia Island

b/ Fort Good Hope - Tieda River

Sources: Environmantal Management Associates (1984) except for data marked " c/ ", " d/ " and " e/ "

c/ R. Bullion (pers. comm)

d/ P. Latour (pers. comm.)

e/ author

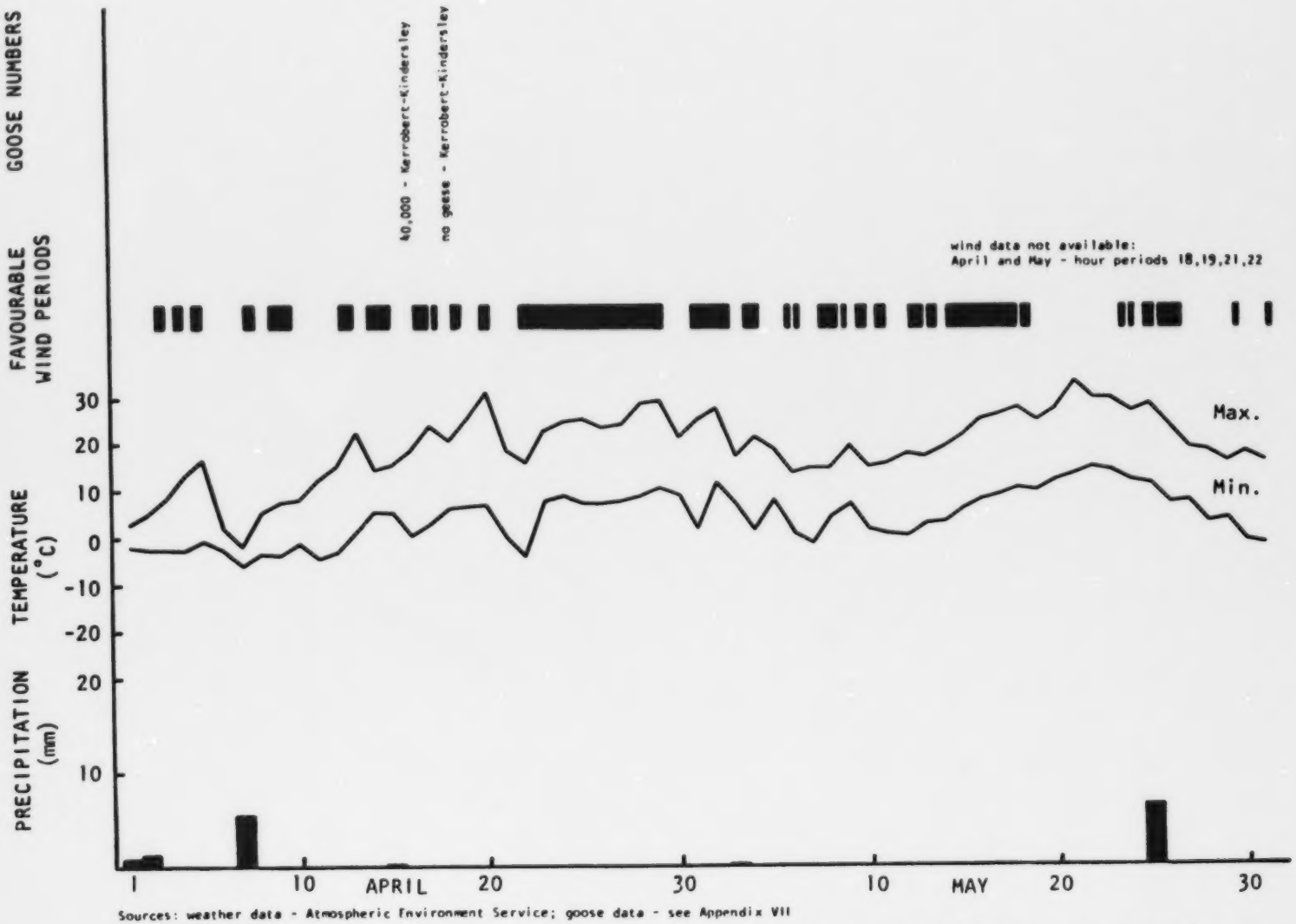
APPENDIX XXI. Detailed analysis of the effects of weather conditions on snow goose migration.

Observations in 1980

On April 7-8, 70 000 snow geese left Freezeout Lake, Montana. By April 16, 40 000 geese had congregated in the Kerrobert-Kindersley, Saskatchewan area. Temperatures at Kindersley had risen from a high on April 10 of less than 10°C to 22.5°C on April 13 (Figure 1). On April 13, winds became favourable for the morning and again for the afternoon of the 14th and morning of the 15th, immediately preceding the large goose concentration near Kindersley. Winds became favourable once more towards the end of the 16th and for most of the 17th. All geese had left the area by the 18th.

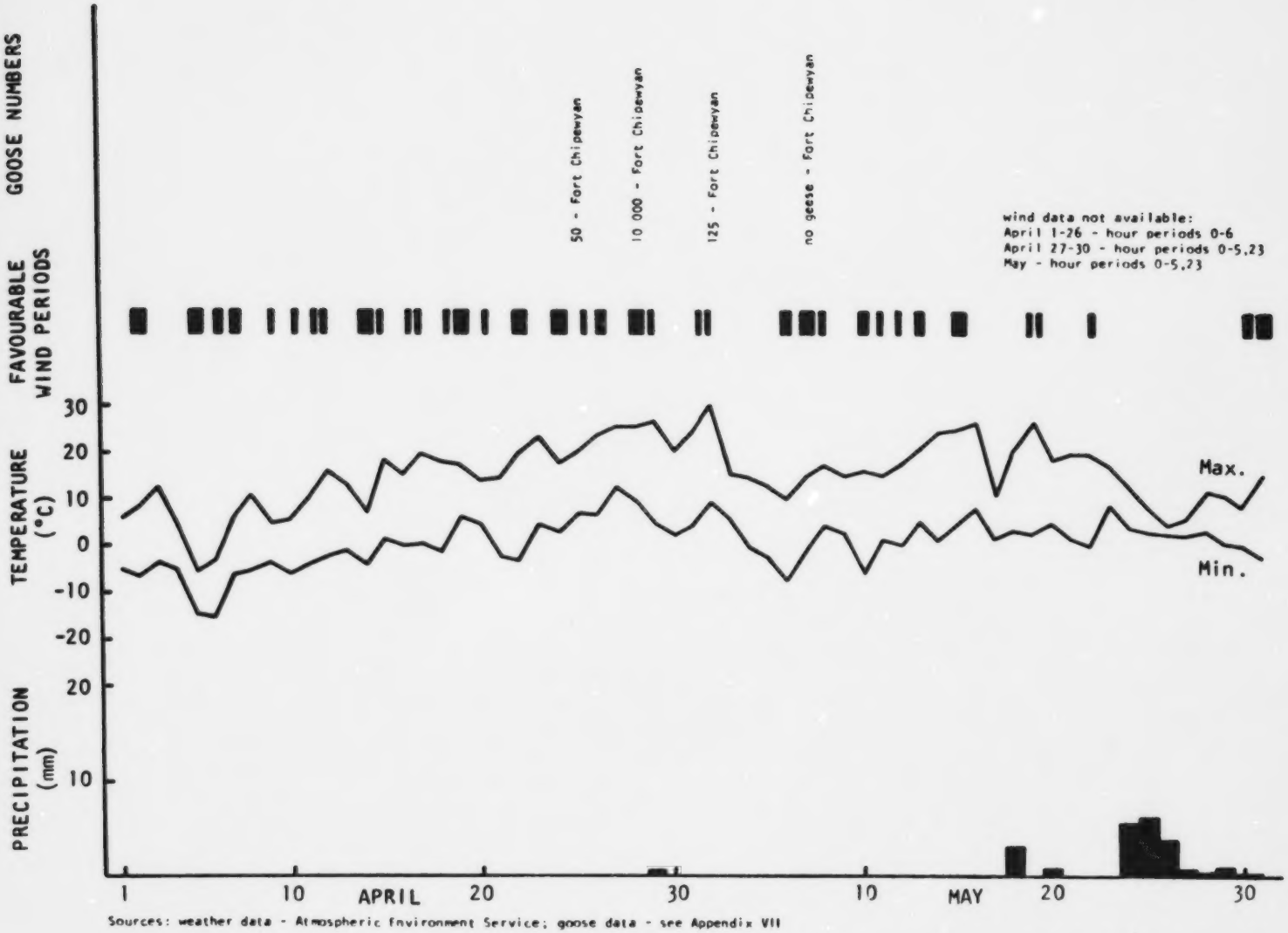
Snow geese were not present in large numbers in the Fort Chipewyan, Alberta area until April 28 when 10 000 were observed. Winds had become favourable on the 28th and persisted for half of the 29th (Figure 2). Only 125 geese were counted on May 2. Winds became favourable again for part of May 6 and for most of the 7th. Geese had left the Fort Chipewyan area by May 7.

On May 2, there were already 9 200 snow geese present in the Norman Wells area. On May 3, 10 000 geese were counted upstream between Keele River and Seagull Island. By May 9, numbers had reached 12 700 at Norman Wells and 11 400 in the upstream reach. Previously, favourable winds were present all day May 5 and for most of the 6th, with precipitation occurring on the 7th and 8th (Figure 3). Winds



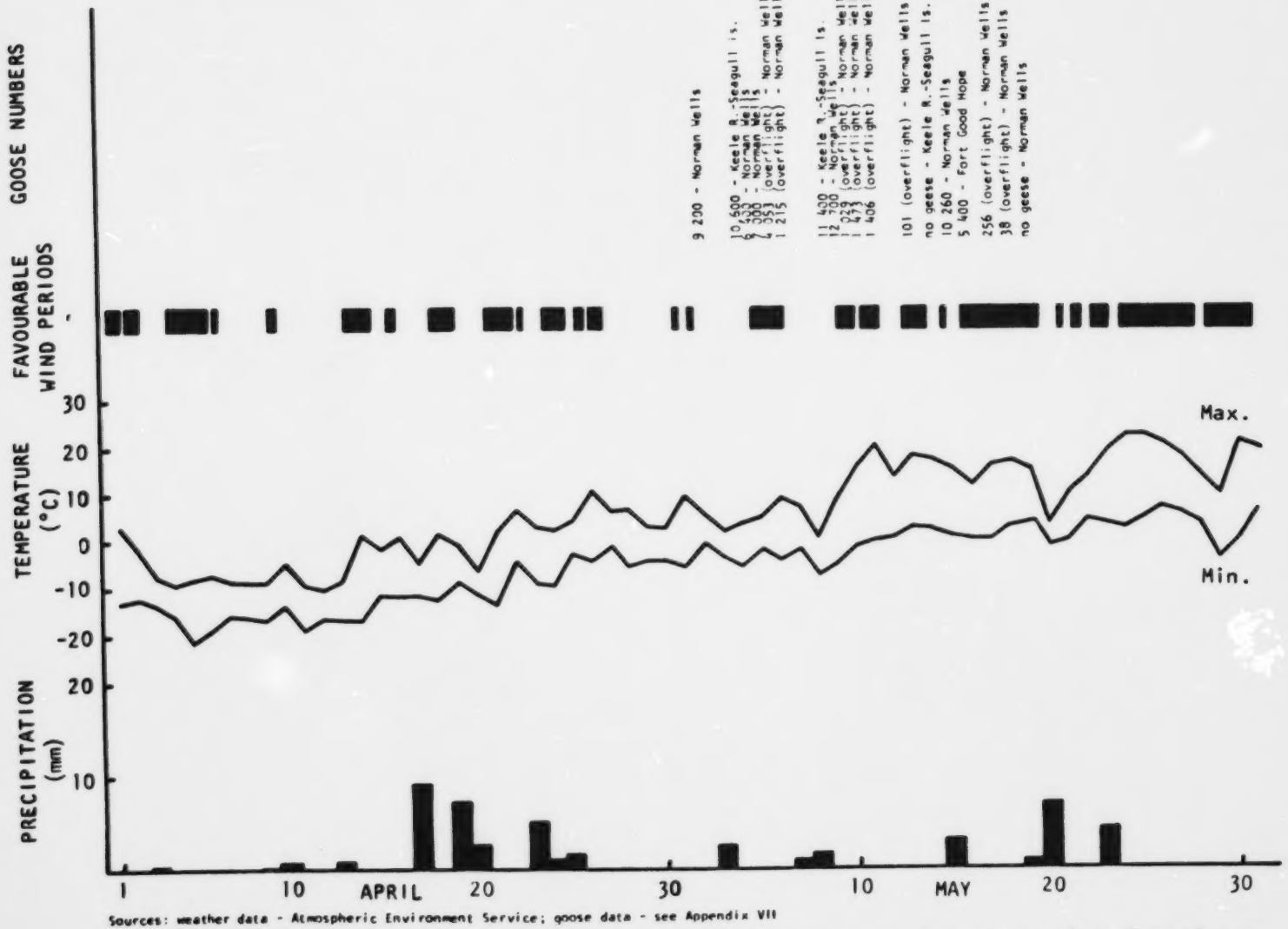
Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VII

Figure 1. Snow goose numbers in relation to precipitation, temperature and wind direction at Kindersley, Saskatchewan in 1980.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VII

Figure 2. Snow goose numbers in relation to precipitation, temperature and wind direction at Fort Chipewyan, Alberta in 1980.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VII

Figure 3. Snow goose numbers in relation to precipitation, temperature and wind direction at at Norman Wells, N.W.T. in 1980.

became favourable again towards the end of May 9, and persisted almost continuously until the latter part of the 11th, resuming again all day on the 13th. No geese were recorded in the Keele River-Seagull Island reach on May 14. On May 15, 5 400 geese were observed in the Fort Good Hope - Tieda River reach while there were 10 260 geese still present in the Norman Wells area. Winds were continuously favourable from the beginning of May 16 to the end of the 19th. A count made on May 19 revealed that all snow geese had left the Norman Wells area. Breakup had occurred a day earlier on May 18.

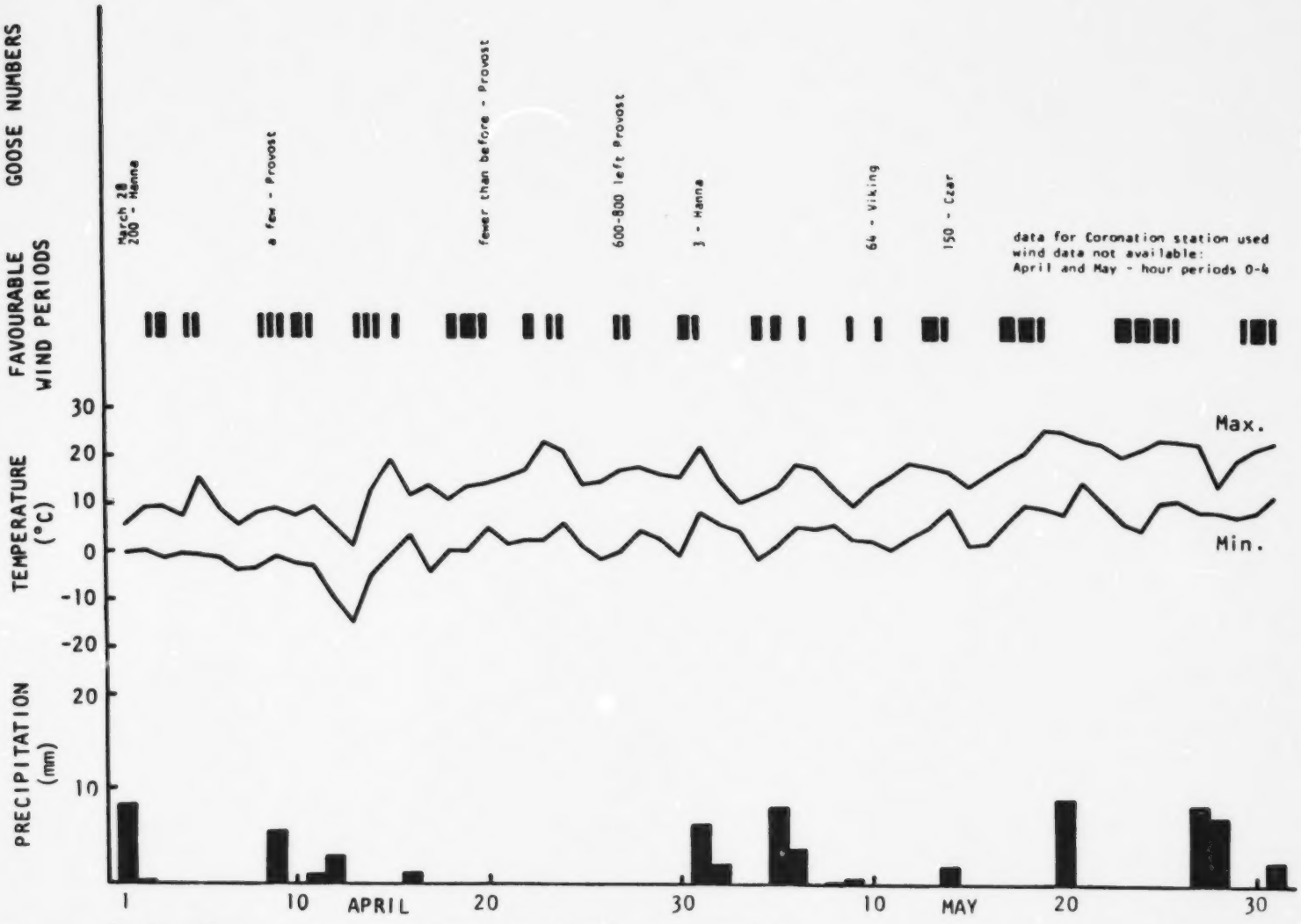
The above shows that there were several instances in 1980 where favourable winds either preceded or coincided with movements of snow geese to or from various staging areas located along the migration route. Data collected by R. Webb Environmental Services Ltd. (1980) on snow goose overflights and arrivals at or departure from the Norman Wells area documents further the relationship between wind direction and snow goose movements. Figure 14 shows that all overflights occurred on days when favourable winds were either continuous or prevalent. In addition, with the exception of May 8, all arrivals and departures occurred on favourable wind days (R. Webb Environmental Services Ltd. 1980). On May 8, 595 snow geese were observed flying upstream from Goose Island coinciding with colder temperatures, snowfall and unfavourable winds (out of the N-W quadrat).

Observations in 1981

On March 22-23, 80-100 000 snow geese were present at Freezeout Lake, Montana. On March 28, 50 to 60 were seen in the Hanna, Alberta area and an additional 200 were observed south of Hanna. Winds were favourable at Coronation (located between Hanna and Provost, Alberta) for more than half of April 8 and half of the 9th, with precipitation occurring on the 9th (Figure 4). A few geese arrived in the Provost area on April 9.

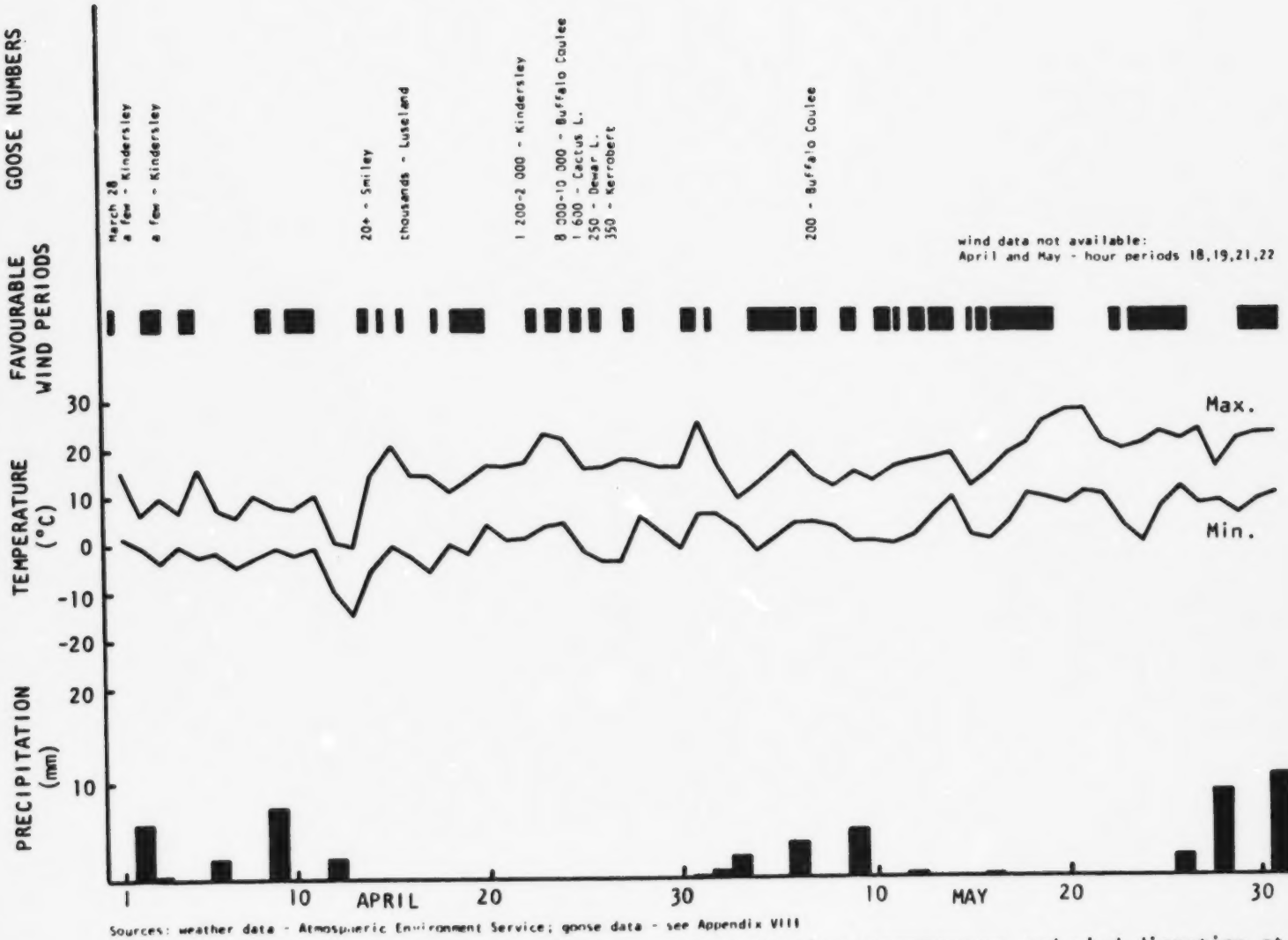
A few snow geese were present in the Kindersley, Saskatchewan area between April 3 and 10. Favourable winds occurred in the area for half of April 9 and 10 and all day on the 11th, returning for a half day on April 14 (Figure 5). On April 16 at Luseland, Saskatchewan (northwest of Kindersley), thousands of geese were observed feeding in stubble fields. In northern Saskatchewan, winds were favourable for half of April 9 and 10 and all of the 11th at Meadow Lake (Figure 6). On April 10, approximately 20 000 geese were noted at Shallow Lake (in the Meadow Lake area).

Back in the southern prairies at Coronation, Alberta, favourable winds returned for parts of April 18, 19 and 20. On April 20, there were fewer geese observed than before. Winds were favourable at Kindersley from late on April 18 to mid-day on the 20th. On April 22, 1 000-1 200 geese were observed at Kindersley and, on April 24, 8 700-10 000 were recorded at Buffalo Coulee, north of Kindersley. Small flocks were also noted at other locations in the Kindersley-Kerrobert area.



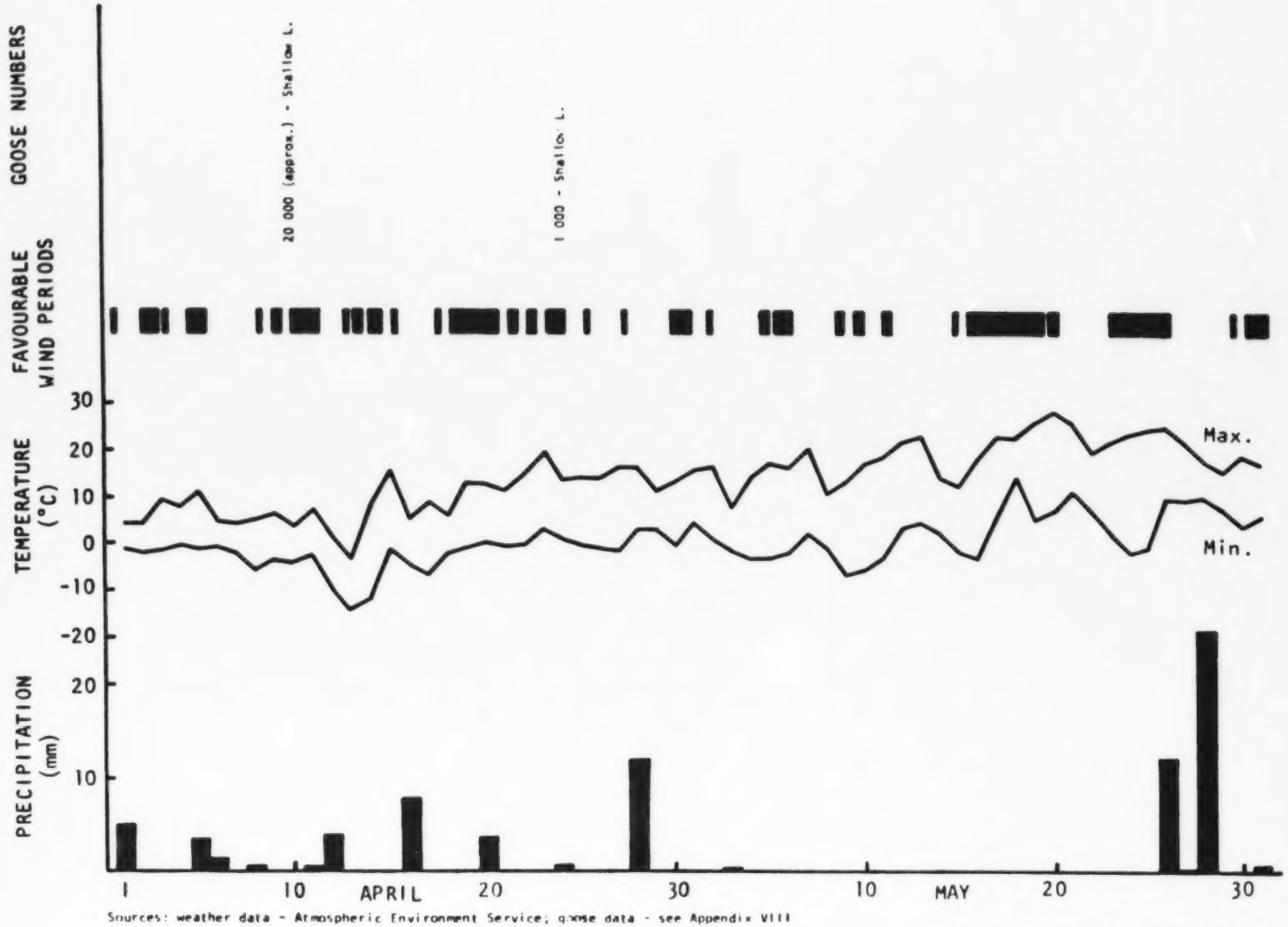
Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

Figure 4. Snow goose numbers in relation to precipitation, temperature and wind direction at Provost/Coronation, Alberta in 1981.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

Figure 5. Snow goose numbers in relation to precipitation, temperature and wind direction at Kindersley, Saskatchewan in 1981.

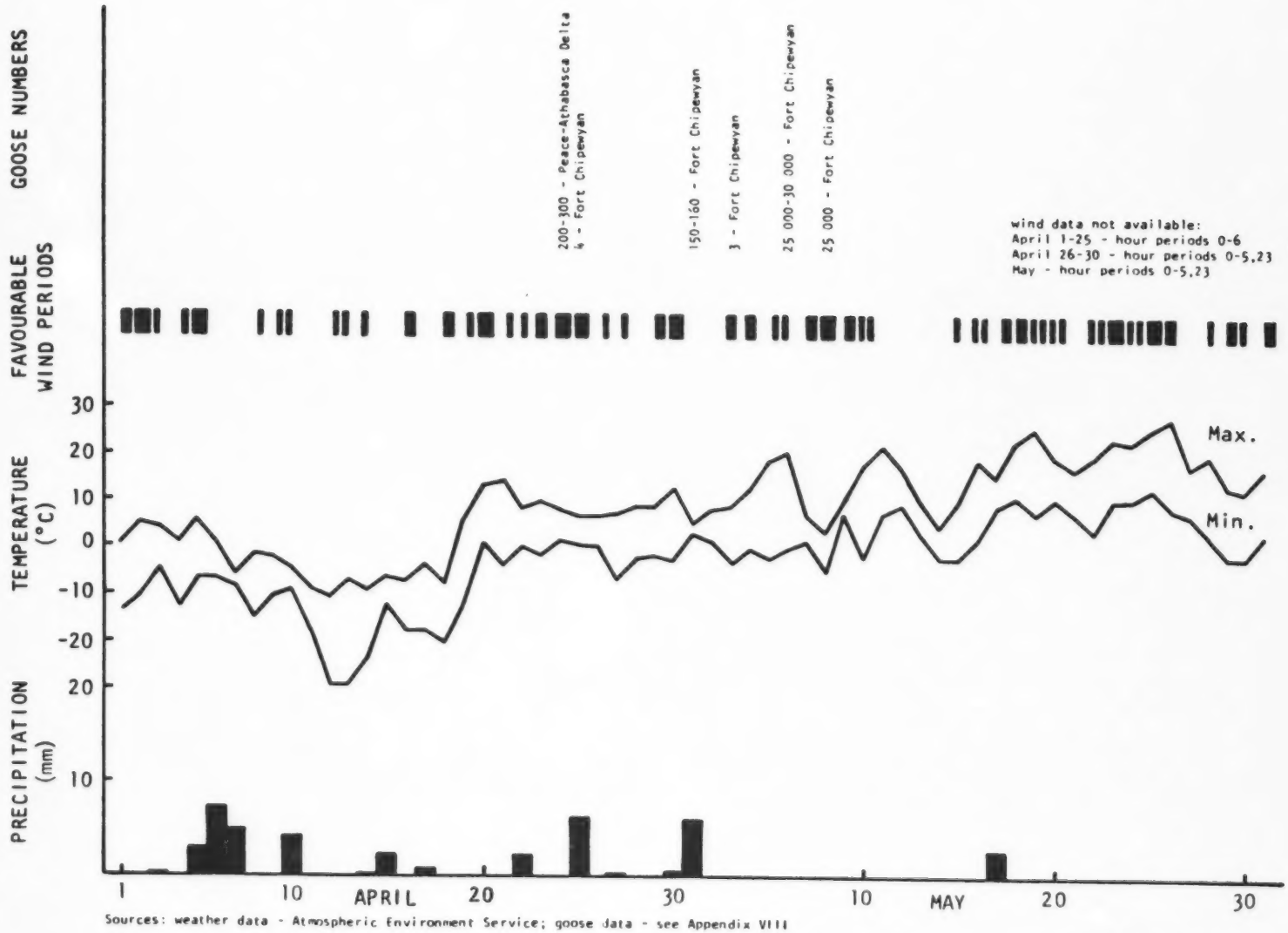


Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

Figure 6. Snow goose numbers in relation to precipitation, temperature and wind direction at Meadow Lake, Saskatchewan in 1981.

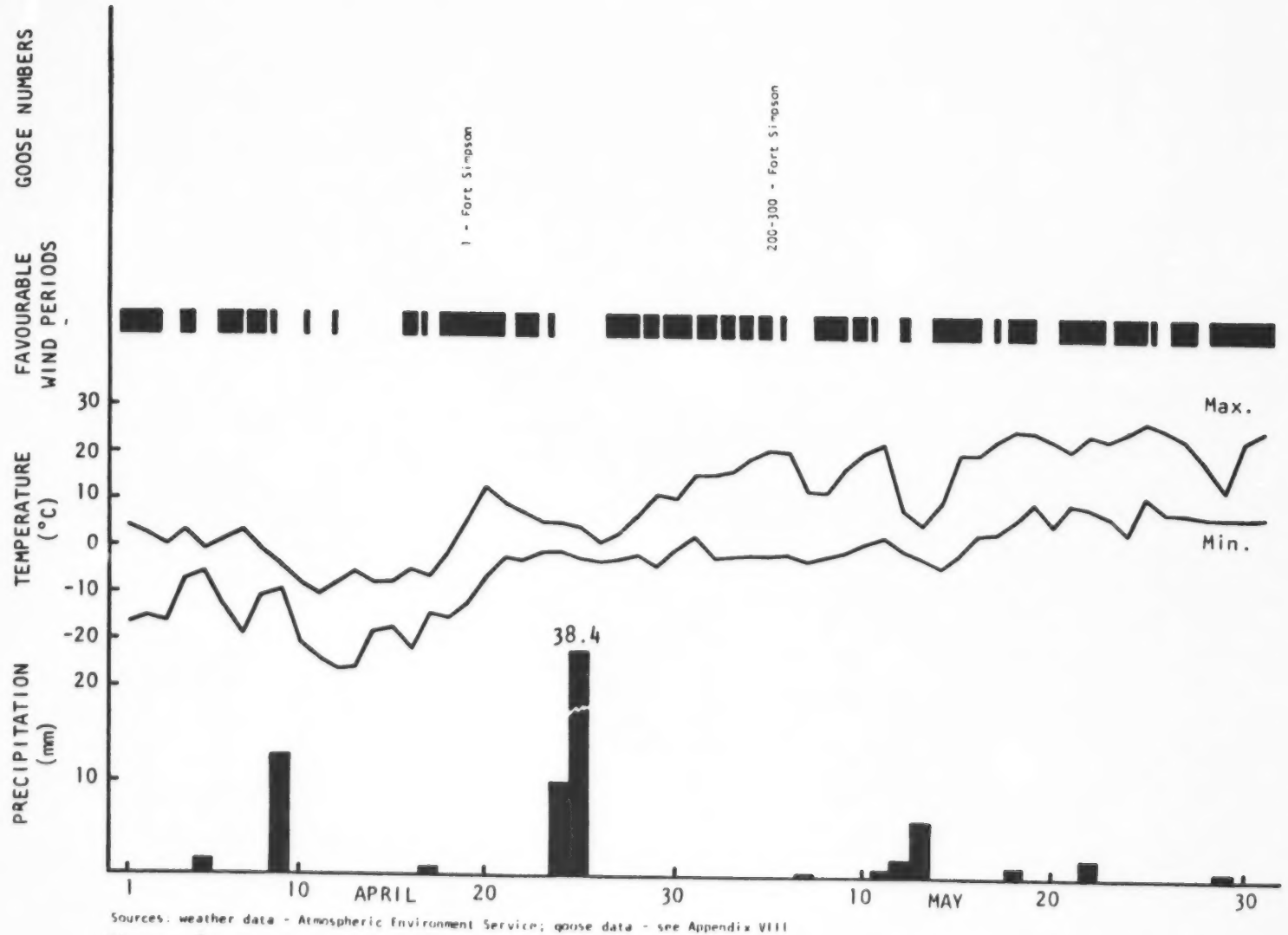
The Meadow Lake area similarly experienced a period of favourable winds which prevailed continuously between the latter part of April 18 and the early part of the 21st and continuing for half of the 22nd and 23rd and most of the 24th. Precipitation fell on April 20 (Figure 6). Numbers of snow geese at Shallow Lake had declined to 1 000 by April 24. Further north in the Fort Chipewyan area, winds were favourable for most of April 20, for parts of April 21, 22, 23 and most of the 24th and 25th. However, precipitation occurred on April 22 and 25 (Figure 7). A small flock of 200-300 geese was seen at the Peace-Athabasca Delta on April 24.

In the Northwest Territories, there were extensive periods of favourable winds at both Fort Simpson and Norman Wells (Figures 8 and 9). At Fort Simpson, this period extended from April 18 to 21. A single snow goose was sighted on April 19. At Norman Wells, the favourable winds lasted from April 18 to the beginning of the 25th. Some geese were observed in the Norman Wells area and approximately 50 were seen downstream from Fort Good Hope. On April 24 and 25, at Fort Simpson, unfavourable winds were accompanied with precipitation (38.4 mm on the 25th). Favourable winds resumed on April 26, continued all day on the 27th, most of the 28th and 29th, all day on the 30th and most of May 1 through 5. Numbers of geese at Fort Simpson had increased to 200-300 by May 5. Wind patterns were similar at Norman Wells (Figure 9). Winds were favourable on April 26 and 27, parts of the 28th, 29th and 30th, all day on May 1 and 2 and for most of the 3rd and 4th. Snow goose numbers increased to 435 by May 2 and 1 250 on May 5. Meanwhile at Fort Chrpewyan, numbers of geese had reached 25-



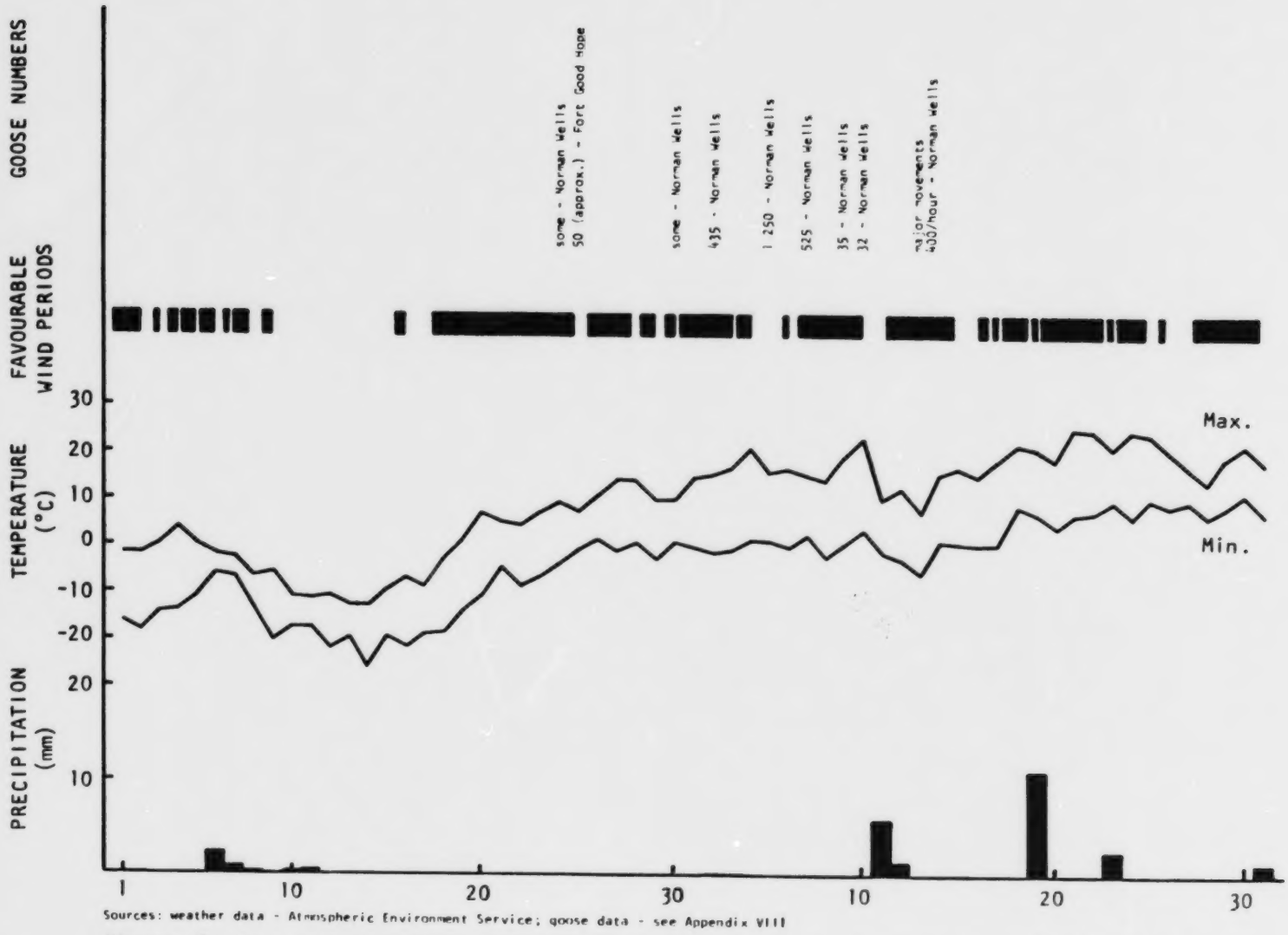
Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

Figure 7. Snow goose numbers in relation to precipitation, temperature and wind direction at Fort Chipewyan, Alberta in 1981.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

Figure 8. Snow goose numbers in relation to precipitation, temperature and wind direction at Fort Simpson, N.W.T. in 1981.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix VIII

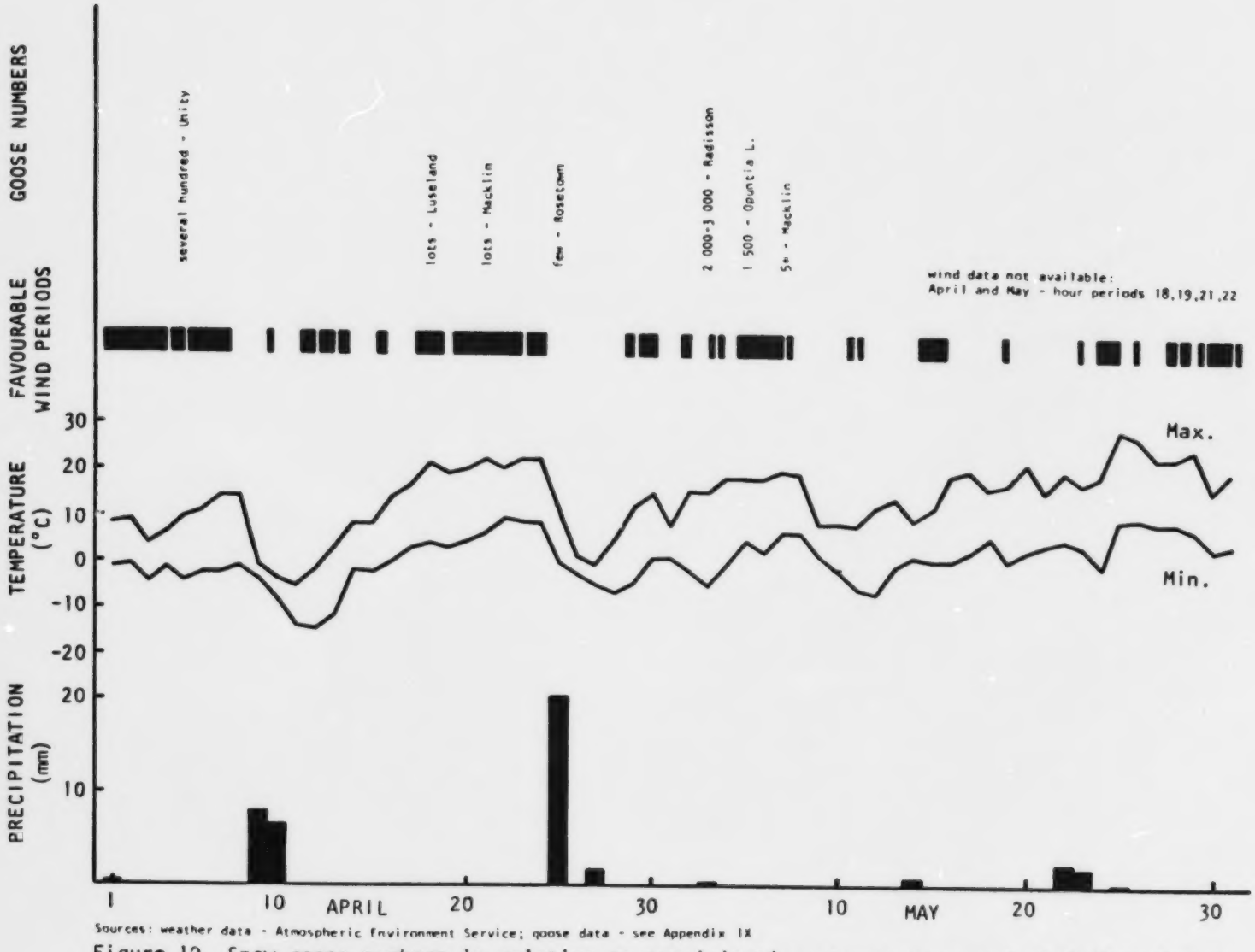
Figure 9. Snow goose numbers in relation to precipitation, temperature and wind direction at Norman Wells, N.W.T. in 1981.

30 000 by May 6. Limited periods of favourable winds had occurred sporadically since April 25 (Figure 7). At Norman Wells, winds were favourable all day on May 7, 8 and 9 and for half of May 10. Numbers of geese had reduced to 525 by May 7 and 35 by May 9. Favourable winds resumed at the end of May 11 and continued all day on the 12th, 13th and 14th. As was noted in section 5.12, an ice jam formed just downstream from Norman Wells on May 11 causing water levels to rise rapidly and almost totally flood Goose Island. Movements of geese through the Norman Wells area were reported on May 13, reaching as many as 400 per hour (R. Webb Environmental Services Ltd. 1983).

From the above observations, it is evident that, in 1981, some movements of snow geese to and from staging areas along the migration route appeared to accompany periods of favourable winds.

Observations in 1983

A large movement of snow geese from Freezeout Lake, Montana occurred on April 1. In the Kindersley area, winds were favourable almost continuously between April 1 and 7 (Figure 10). On April 5, several hundred geese were noted at Unity, Saskatchewan, about a hundred kilometres north of Kindersley. Until April 18, winds were largely unfavourable at Kindersley. A substantial drop in temperature was accompanied by snow on April 9 and 10. Favourable winds returned for a largely uninterrupted period between April 18 and 24. Over 20 mm of precipitation fell on the 25th. "Lots" of geese (more specific data not available) were observed at Luseland and Macklin (north of Kindersley) on April 18 and 21, respectively. A small flock of snow



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix IX

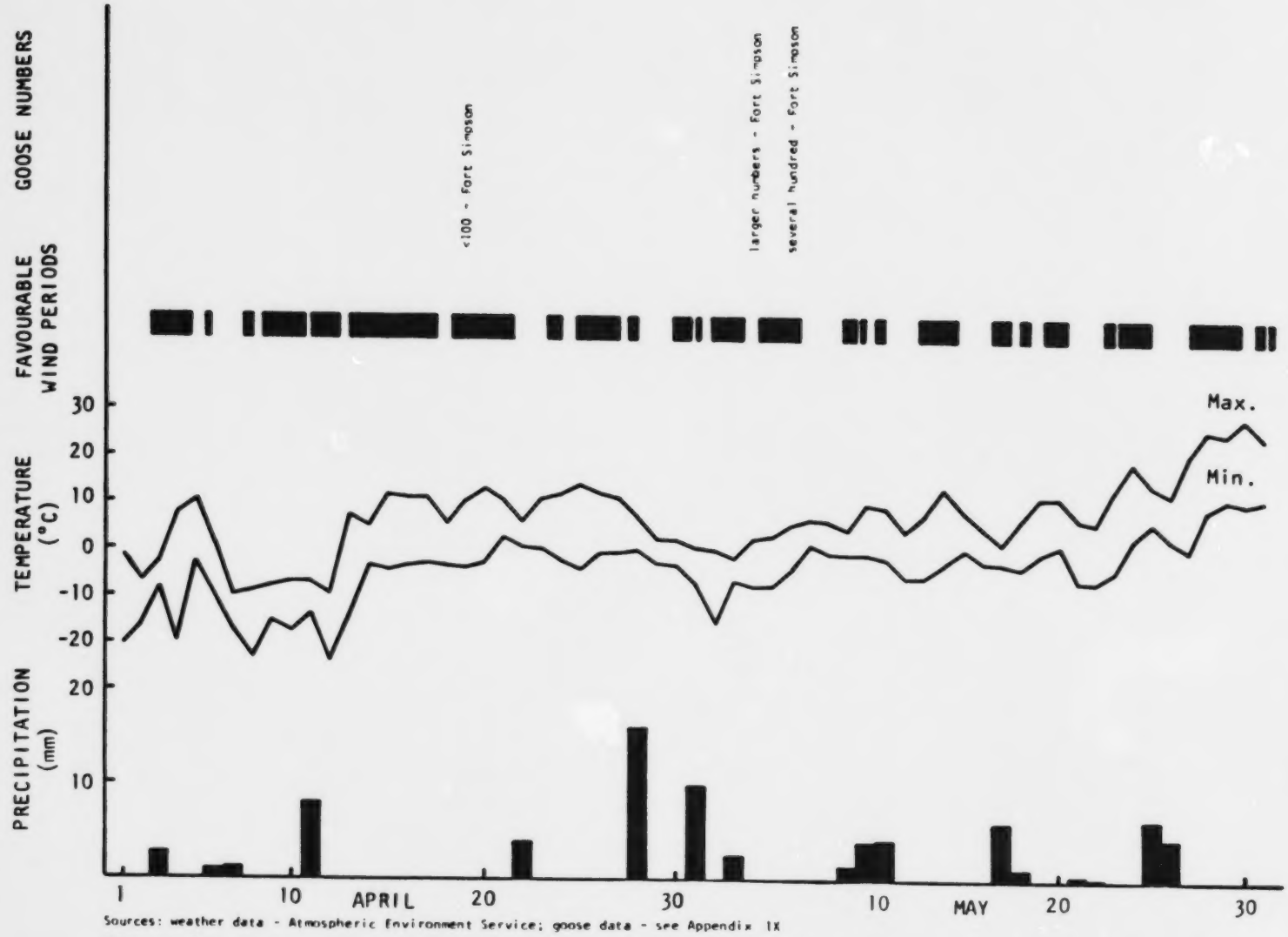
Figure 10. Snow goose numbers in relation to precipitation, temperature and wind direction at Kindersley, Saskatchewan in 1983.

geese (less than 100) had already arrived at Fort Simpson by April 19. After a period of low temperatures from April 7 to 12, and snow on the 11th, warmer weather was accompanied by favourable winds which extended almost continuously between April 14 and 21 (Figure 11).

On April 25, only a few geese were present at Radisson, Saskatchewan, east of Kindersley. Winds were favourable for parts of April 29 and 30 and May 2. On May 3, between 2 000 and 3 000 geese were present at Radisson, and on May 5 there were 1 500 at Opuntia Lake (northeast of Kindersley). Winds were favourable again all day on May 5 and 6 and for most of the 7th. On May 7, there were less than 10 geese left at Macklin, Saskatchewan.

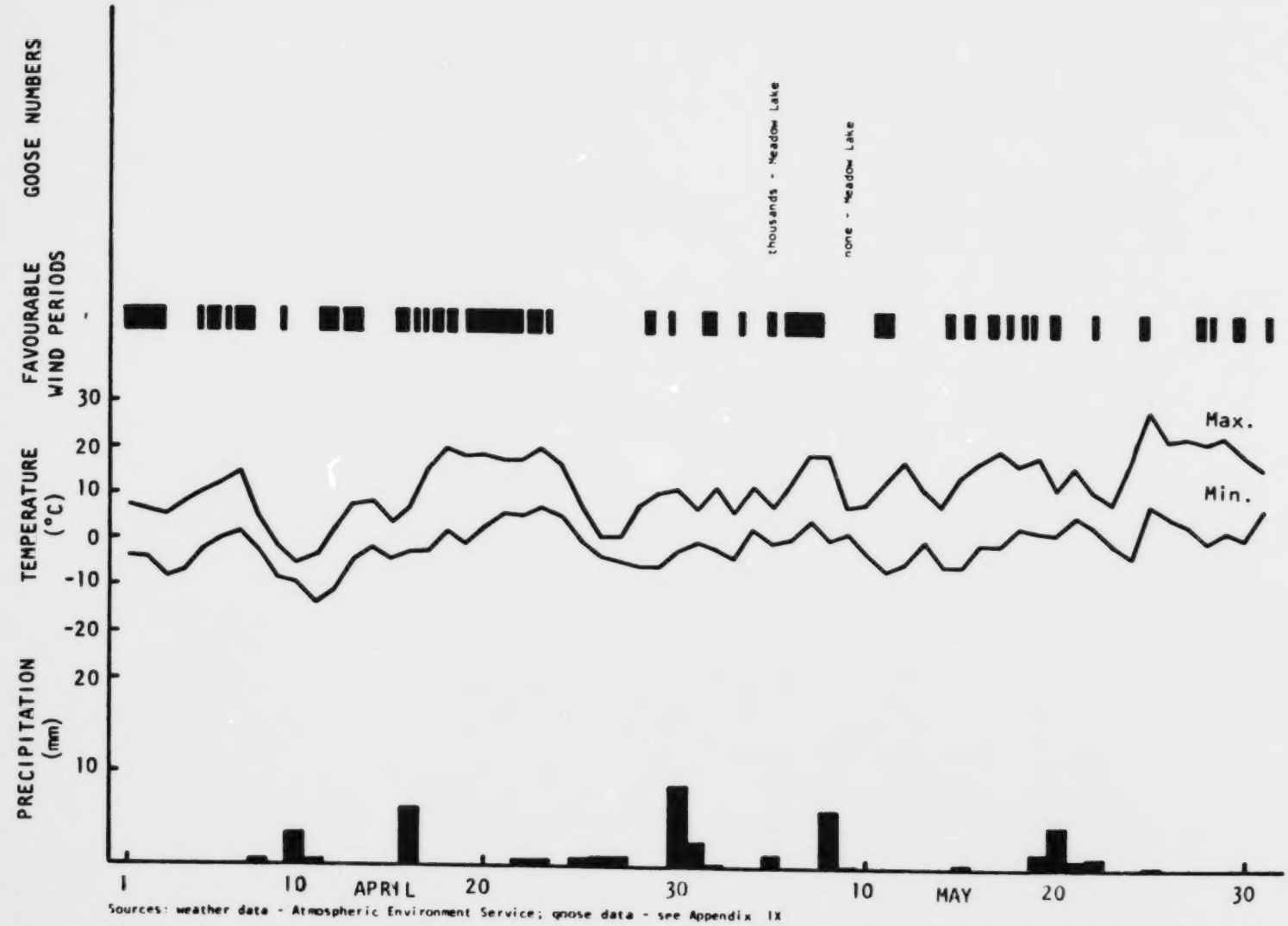
In the northern prairies, there were thousands of geese at Meadow Lake on May 5. Favourable winds began on May 6 and continued until early on May 8 (Figure 12). On May 9 there were no geese left at Meadow Lake. On May 3, there were 2 500 geese at Fort Chipewyan, Alberta. Previously, winds had been favourable only sporadically and for brief periods (Figure 13).

Since the first sighting of geese at Fort Simpson on April 19, there were several periods of favourable winds before larger numbers were observed on May 4 (Figure 11). Winds were favourable again on May 5 and 6 and on May 6, several hundred geese were present. Winds were mostly favourable at Norman Wells between May 1 and 6 (Figure 14). The first snow geese at Norman Wells were observed on May 4. By May 8 there were 205 geese present, increasing to 827 on May 10. Winds were



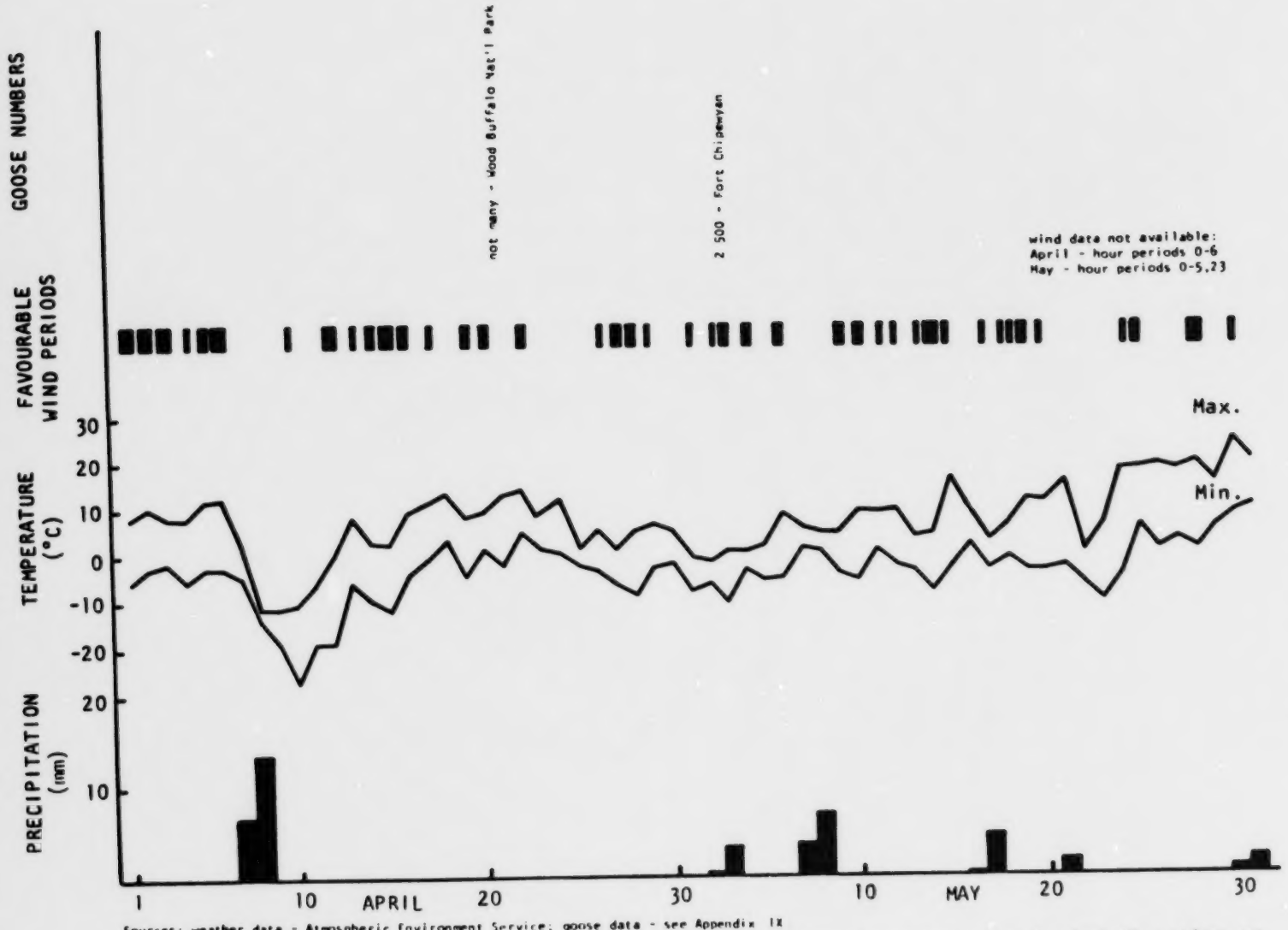
Sources: weather data - Atmospheric Environment Service; goose data - see Appendix IX

Figure 11. Snow goose numbers in relation to precipitation, temperature and wind direction at Fort Simpson, N.W.T. in 1983.



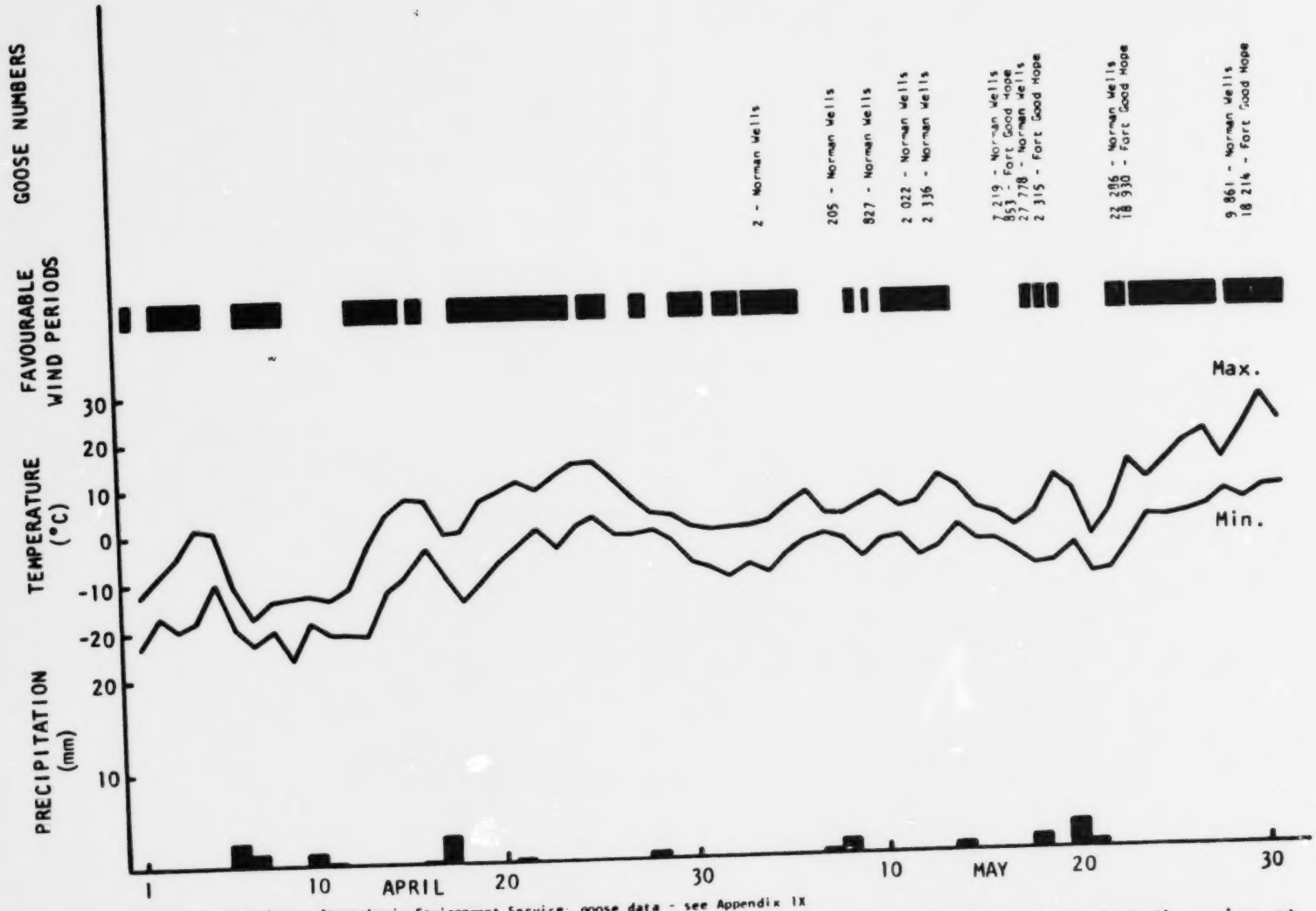
Sources: weather data - Atmospheric Environment Service; goose data - see Appendix IX

Figure 12. Snow goose numbers in relation to precipitation, temperature and wind direction at Meadow Lake, Saskatchewan in 1983.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix IX

Figure 13. Snow goose numbers in relation to precipitation, temperature and wind direction at Fort Chipewyan, Alberta in 1983.



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix IX

Figure 14. Snow goose numbers in relation to precipitation, temperature and wind direction at Norman Wells, N.W.T. in 1983.

favourable all day on May 11, 12 and 13 and the first half of May 14. Snow geese had increased in number to 2 022 on May 12 and 2 336 on May 13. Winds were unfavourable between the latter half of May 14 to early on May 18. However, on May 17 there were 7 219 snow geese at Norman Wells and 853 downstream from Fort Good Hope. A return to favourable winds on May 18 was accompanied by an increase in goose numbers to 27 778 at Norman Wells and 2 315 in the Fort Good Hope area. By May 23, numbers of geese were down to 22 286 at Norman Wells but had increased to 18 930 in the Fort Good Hope area. A day later, the Norman Wells area had experienced further reductions (9 861 geese) while there were still 18 214 geese observed in the Fort Good Hope area. Subsequently, a period of favourable winds extended from May 24 into May 28. On May 29, only two geese were observed at Norman Wells and virtually all geese had left the Fort Good Hope area.

In summary, periods of favourable winds in 1983 were accompanied with movements of snow geese at a number of locations along their migration route.

Observations in 1984

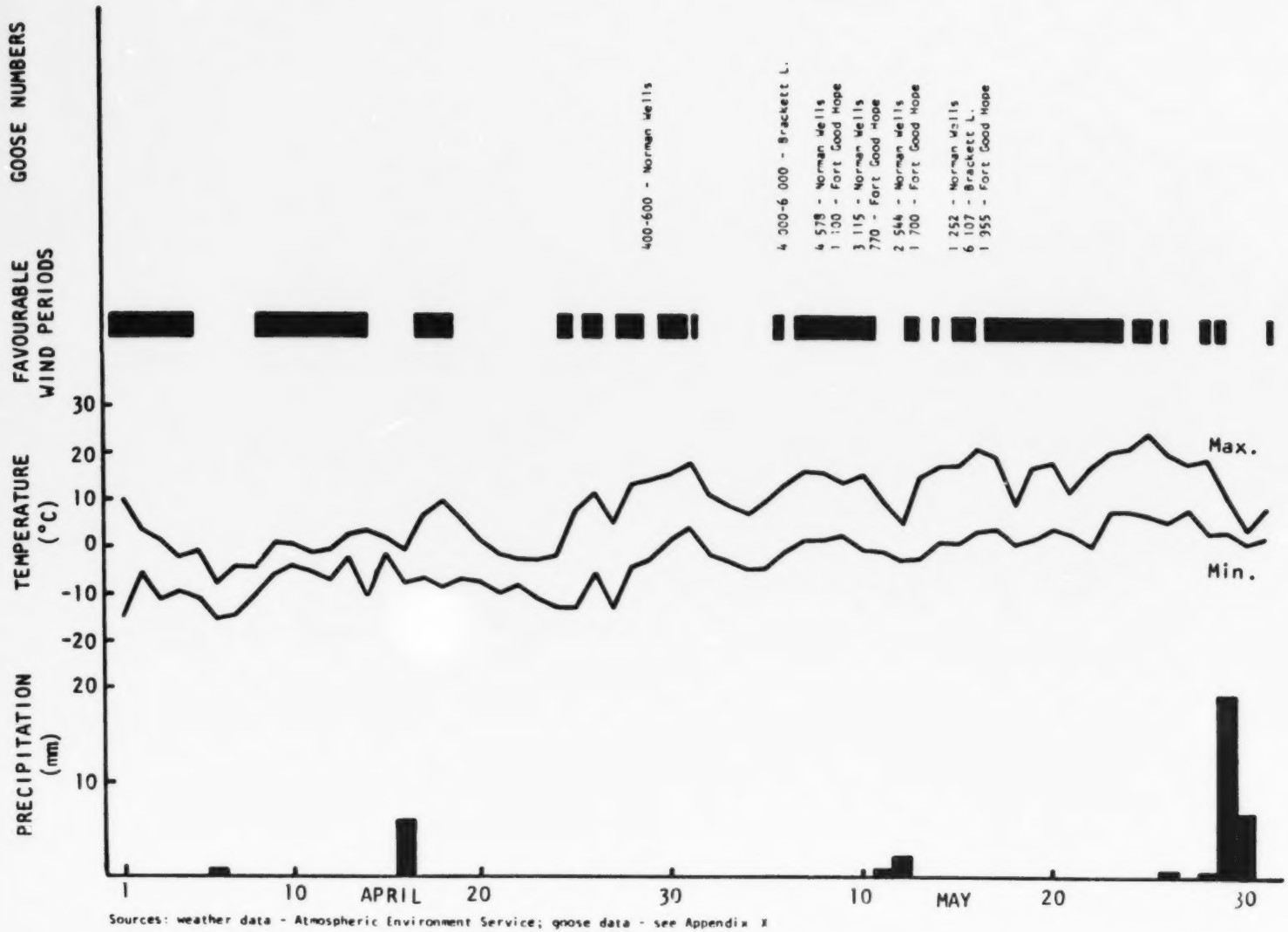
Environmental Management Associates has monitored spring and fall goose migration through telephone communication with observers in the prairies and Northwest Territories since the spring of 1980. Much of the data in Appendixes XVII to XX is the result of this work. According to D. Young (pers. comm.), the techniques used in the spring of 1984 were no different from those used in previous years and yet very few observations of snow goose flocks were recorded in Alberta and

Saskatchewan in 1984 (Appendix XX). It is likely that extremely dry conditions, warm temperatures and an early spring stimulated the snow geese to fly north with little delay.

Observations at Norman Wells similarly did not follow the usual course of events. The largest number of snow geese observed in the Norman Wells area (Bear Island - Mac Island) during the 1984 study period was 2 225 on May 8. This was substantially less than the peak reported for this reach in 1983 of 14 928, although it exceeded the maximum of 500 birds observed in 1981.

Between 400 and 600 snow geese were present in the Norman Wells area by April 29. The first extended period of favourable winds began on May 7 and lasted until May 10 (Figure 15). During this period, snow goose numbers at Norman Wells dropped from 4 578 on May 8 to 3 115 on May 10. Similarly, numbers downstream from Fort Good Hope dropped from 1 100 to 700. Although winds were unfavourable, numbers at Fort Good Hope increased to 1 700 on May 12, while at Norman Wells, a further reduction to 2 544 was experienced. Following another period of mostly unfavourable winds, further increases at Fort Good Hope and decreases at Norman Wells took place.

Observations of arrivals of snow geese at, and departures from, Norman Wells made by R. Webb Environmental Services Ltd. (1984) confirm movements of snow geese during periods of unfavourable winds. The largest numbers of geese were observed to arrive on May 4 (4 125 birds) and May 5 (6 625 birds). Winds were unfavourable on both days (Figure 15).



Sources: weather data - Atmospheric Environment Service; goose data - see Appendix X

Figure 15. Snow goose numbers in relation to precipitation, temperature and wind direction at Norman Wells, N.W.T. in 1984.

The preceding discussion indicates that, in the spring of 1984, there was very little correlation between the timing of snow goose movements and wind direction in the Norman Wells area. It appears that migration did not proceed in the normal manner with large snow goose flocks building up at key areas located progressively further downstream on the Mackenzie River. In section 4.11, it was noted that, on May 15, there were more snow geese in the Brackett Lake area, north of Fort Norman, than on the whole length of the Mackenzie River reaches surveyed that same day. Snow geese had been observed at Brackett Lake as early as April 2 and were seen at Paulatuk on the arctic coast on May 3, about two weeks earlier than normal (Bellrose 1976).